COLONISATION PATHWAYS OF AN INTERMITTENTLY FLOWING STREAM IN RELATION TO A CHANGING FLOW REGIME AND SEASONALITY

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"When you are a Bear of Very Little Brain, and you Think of Things, you find sometimes that a Thing which seemed very Thingish inside you is quite different when it gets out into the open and has other people looking at it."

"*Winnie-the-Pooh*"

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ABSTRACT

Invertebrate colonisation pathways were investigated in relation to a changing flow regime and seasonality in a stream with an intermittently flowing lower course at Cass, inland Canterbury. Benthic, drift, hyporheic and non-aquatic adult invertebrate faunas were sampled over a 12 month period, from November 1996 to November 1997. During this period, the stream channel in the lower, grassland reach dried up for three months, from late January to late April, and recolonisation of this reach was assessed following flow resumption. Colonisation pathways operating in both forest and grassland sections of the permanently flowing upper reach were also assessed.

At the perennially flowing forested and grassland sites, invertebrate drift, oviposition by flying adult insects, and vertical migration from the hyporheos all contributed to colonisation of the benthos. Assemblages of invertebrates using the three pathways and the two riparian biotopes (forest and grassland) differed to varying degrees, with drift and flight activity of potential colonists being greatest during summer.

Invertebrate drift from the perennially flowing upper reaches and oviposition by flying adults appeared to be the main sources of colonists of the intermittent grassland reach when flow resumed in autumn following a three month dry period. The hyporheic zone was of limited importance as a refuge when the channel dried up, since subsurface water disappeared rapidly following the loss of surface flow. Recolonisation of the benthos was gradual, as both drift and ovipositing adults contributed relatively low numbers of colonists in late autumn and winter.

Local conditions, particularly substratum type (which affects hyporheic drainage) and proximity to permanent water bodies (sources of colonists), were important determinants of the colonisation pathways used by invertebrates following flow resumption in the intermittent reach. It will be important to take such local factors into consideration when making predictions about recolonisation pathways operating in other New Zealand streams and rivers.

CHAPTER ONE
INTRODUCTION

Running waters may be classified as being permanent or intermittent, according to their flow regime. Permanent streams exhibit continuous flow, whereas intermittent streams periodically cease flowing, often on a regular, seasonal basis (Boulton & Lake, 1988; Gordon *et al.*, 1992; Williams, 1996). Considering the common occurrence of intermittent streams around the world, they have been the subject of surprisingly little research. Recently, however, the ecology of temporary streams has received more attention, particularly in Australia (for example: Boulton, 1989; Brooks & Boulton, 1991; Boulton & Lake, 1992; Boulton *et al.*, 1992a; Cooling & Boulton, 1993; Paltridge *et al.*, 1997) and North America (for example: Delucchi, 1988, 1989; Delucchi & Peckarsky, 1989; Anderson & Dieterich, 1992; Boulton *et al.*, 1992b; Stanley *et al.*, 1994; Boulton & Stanley, 1995; Clinton *et al.*, 1996, Feminella, 1996; Jacobi & Cary, 1996; Millar & Golladay, 1996).

When an intermittent stream dries, the aquatic inhabitants must adopt strategies that enable them to avoid or tolerate desiccating conditions within the streambed (Boulton *et al.*, 1992a). To do this macroinvertebrate species are likely to "adopt" resistant or resilient strategies (Boulton *et al.*, 1992a). Resistance of desiccating conditions generally requires specialised behavioural or physiological adaptations, which enable organisms to remain in the dry streambed until flow resumes. Physiological adaptations include survival as desiccation resistant eggs (Towns, 1983a; Wright *et al.*, 1984; Delucchi & Peckarsky, 1989; Jacobi & Cary, 1996) or pupae (Clifford, 1966). Some snails secrete an epiphragm over their shell aperture to reduce water loss (Boulton & Lake, 1988), and the caddisfly, *Diplectrona modesta* Banks, can survive curled up within its case for at least four weeks in a shaded, humid streambed (Imhof & Harrison, 1981). Alternatively, resistance strategies may involve behavioural avoidance of desiccating conditions, by exploiting moist microhabitats within the streambed. These include the hyporheic zone, remaining pools, crayfish burrows, or damp habitat beneath leaf packs, dried algae or wood (Boulton & Lake, 1988).

Resilient macroinvertebrate species may also maintain populations in intermittent streams by rapidly reinvading the stream following flow resumption (Stanley *et al.*, 1994). Such invertebrates generally originate from nearby permanent waters, usually as aerial adults. Some insects that inhabit intermittent streams utilise the adult stage of their lifecycles as a means of avoiding desiccating conditions. For example, adults of the caddisfly *Stenophylax* fly away from drying streams to hibernate in nearby caves, returning to lay eggs when flow resumes (Williams, 1996).

The recolonisation strategy used may reflect the severity of drying of the streambed. Boulton *et al.* (1992a), found that resistance strategies were common in Australia, where moist microhabitats often remained after stream drying. In contrast, resilience was a more common strategy in an Arizona desert, where streambed drying was more severe and extremely high temperatures eliminated moist refuges within the substrate (Boulton *et al.*, 1992a).

While some aquatic taxa possess specialisations that enable them to tolerate intermittently dry conditions, many species that inhabit intermittent streams do not possess such adaptations (Clifford, 1966; Delucchi, 1988; Delucchi & Peckarsky, 1989; Paltridge *et al.*, 1997). Instead, to maintain populations they depend on characteristics shared with many inhabitants of permanently flowing streams, such as high migration and reproductive rates (Delucchi, 1988). Such taxa commonly arrive as adults from nearby permanent streams (Boulton & Lake, 1992), or as larvae from perennially flowing upper reaches (Paltridge *et al.*, 1997).

Because many of the colonists of intermittently flowing streams are derived from nearby permanent waters, considerable overlap in the species composition of intermittent and permanent streams is often found (Clifford, 1966; Boulton & Suter, 1986; Delucchi, 1988, 1989; Delucchi & Peckarsky, 1989; Bunn & Davies, 1990; Boulton & Lake, 1992; Feminella, 1996; Paltridge *et al.*, 1997). This demonstrates that the invertebrate fauna of intermittent streams may not be as unique as suggested by Williams &

Hynes (1977), who stated that their faunas consisted almost solely of invertebrates highly specialised for survival under conditions of intermittent flow. In contrast, Wright *et al.* (1984) documented distinct differences between the faunas of an intermittent upstream reach and a permanently flowing downstream reach of a small chalk stream in England, although even there some species were common to temporary and permanent habitats.

When surface flow resumes in a stream channel following a dry period, invertebrate recolonisation may occur via four main pathways: aerial colonisation, downstream drift, vertical migration from the substrate, and upstream migration (Williams & Hynes, 1976). While all four directions may contribute colonists, their relative importance varies between locations (Mackay, 1992) and taxa (Williams & Hynes, 1976).

The objective of my study was to investigate colonisation pathways used by invertebrates in Middle Bush Stream, Cass, during continuous flow and following flow resumption in the lower, intermittent reach. My research focussed on the following questions:

1) What are the sources of colonists at Middle Bush Stream
    a) when water returns to the stream?
    b) during continuous flow?
2) Do colonisation patterns change seasonally?

In Chapter 2 the environment of Middle Bush Stream is described and details are given of the five study sites and flow characteristics. Chapter 3 presents the results of a seasonal benthic sampling programme in Middle Bush Stream. This aspect of the study provided information on the composition of the benthos and the potential availability of colonists of the downstream reaches by drift in particular. Invertebrate drift is considered in Chapter 4, the hyporheic fauna at Sites 3 and 5 is discussed in Chapter 5, and flight activity of adult mayflies, stoneflies and caddisflies, based on sticky trapping at all five sites, is reported in Chapter 6. Colonisation by upstream movement was examined early in the study (Appendix 5), but it soon became apparent that its importance was minimal: therefore, sampling of this pathway was not pursued further. Finally, a model of the colonisation pathways operating at Middle Bush Stream is presented in Chapter 7, and my findings are considered in relation to those obtained in other investigations of intermittent streams.

CHAPTER TWO
STUDY AREA

Introduction

The study was undertaken at Middle Bush Stream (43° 19′S, 171° 46′E), a tributary of Grasmere Stream in the Cass river basin (Fig. 2.1). Grasmere Stream flows into Cass River which is a major tributary of the Waimakariri River.

Geology and Vegetation

The Waimakariri catchment was formed during a period of uplifting and faulting, and subsequent scouring of major faults during successive glaciations carved out the river valleys seen today (Hayward, 1974). Erosion and sediment transport continue to shape the dynamic landscape at Cass, forming scree slopes, alluvial fans and terraces (Gage, 1977). Vegetation in the Cass region is characterised by tussock grassland, small stands of formerly widespread mountain beech (especially in gullies) and plantings of exotic trees described in greater detail by Burrows (1977).

Climate

Weather patterns in the Cass region are strongly influenced by the surrounding mountains and high altitude (Greenland, 1977). The region experiences high summer and relatively mild winter temperatures (Fig. 2.2a). During the period of my study the maximum temperature recorded at the Cass Biological Station was 31°C, and the minimum was -10°C (Field station unpublished records). An electronic temperature logger positioned in shaded scrub beside Middle Bush Stream recorded a temperature of 36°C in late January 1997, indicating that in sheltered areas in the open, the temperature may exceed that recorded at the field station.

During the 12 months of my study, precipitation (rain and snow) recorded at the Cass field station was 1394 mm, slightly above the average annual rainfall of 1250 mm recorded by Greenland (1977). Rainfall in

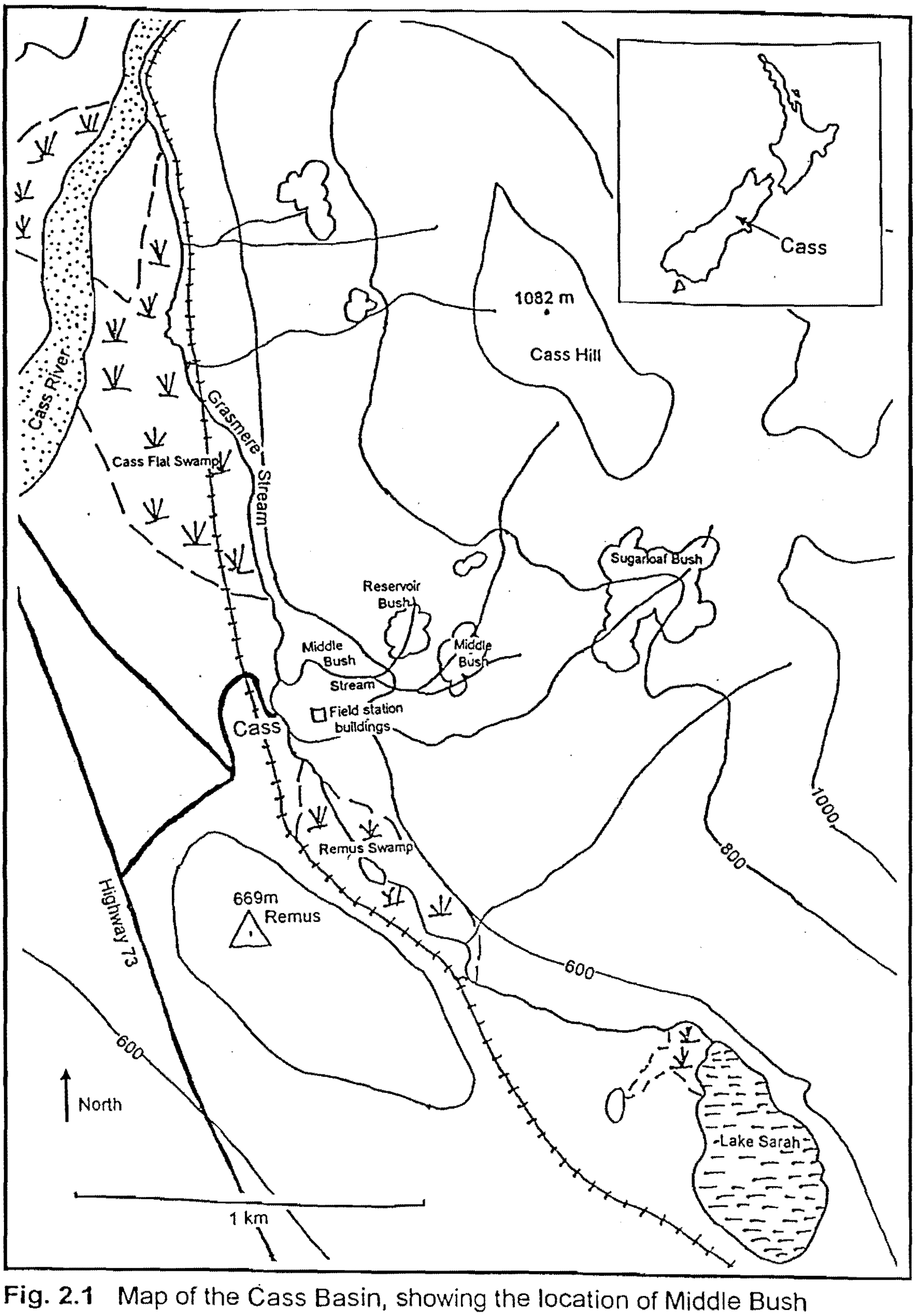
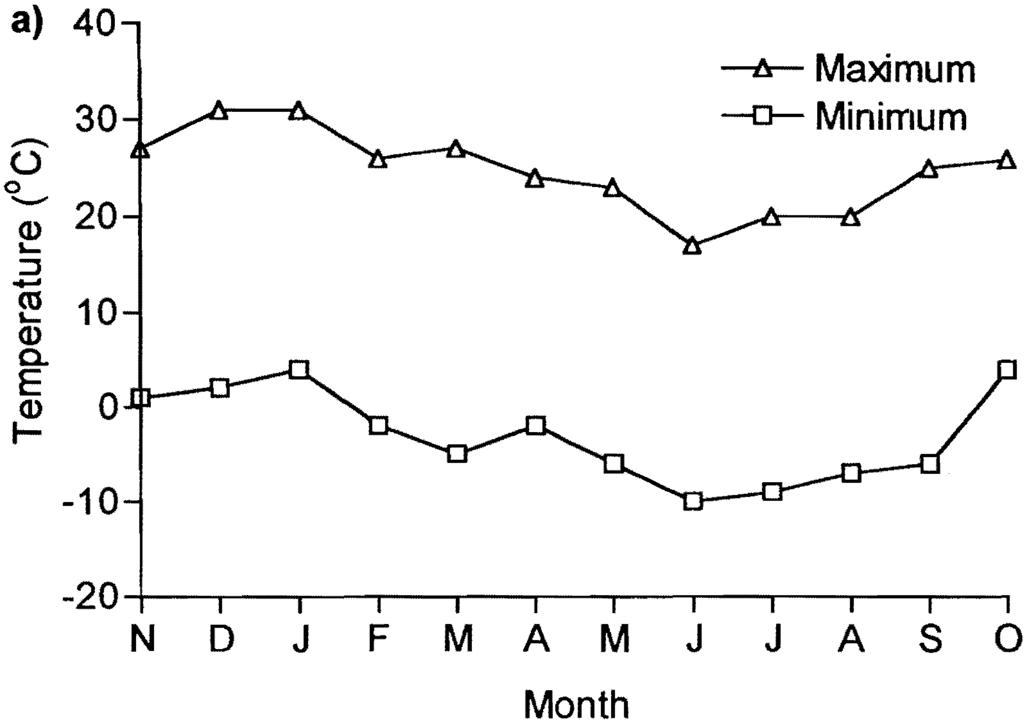


Fig. 2.1 Map of the Cass Basin, showing the location of Middle Bush Stream. The insert shows the position of the Cass Basin in inland Canterbury, South Island, New Zealand.



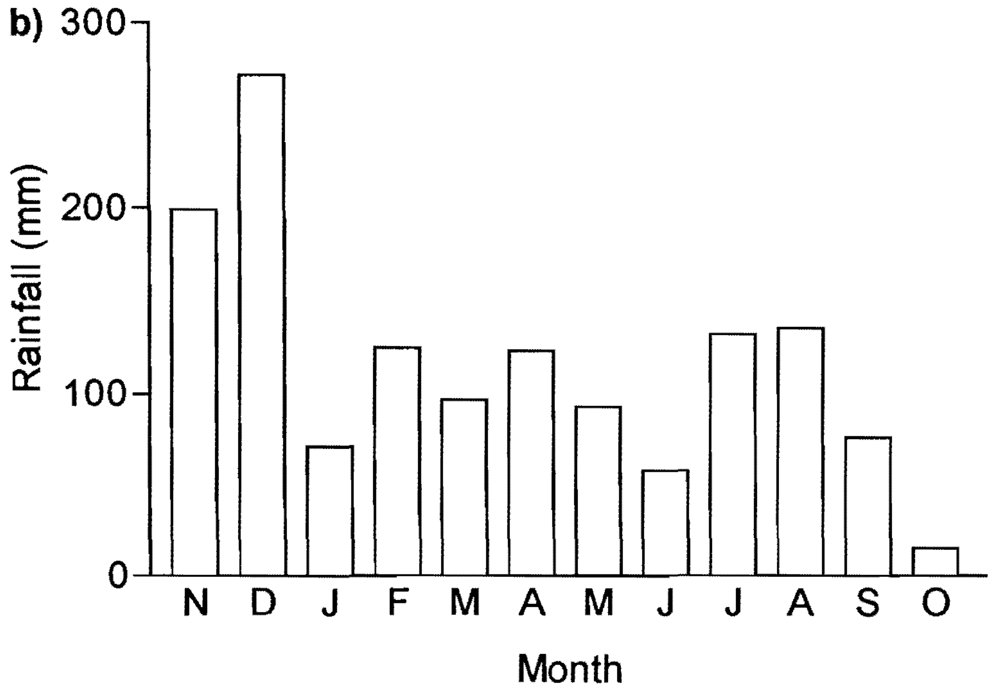


Fig. 2.2 a) Maximum-minimum air temperatures recorded monthly at the Cass Biological Station from 1 November 1996 to 4 November 1997.

b) Rainfall recorded at the Cass Biological Station monthly from 1 November 1996 to 4 November 1997.

November and December 1996 was relatively high (471 mm) compared to that recorded in 1993 (~235 mm; Shearer, 1995) and 1995 (~155 mm; Adkins, 1997) (Fig. 2.2b). High rainfall (~390 mm) was recorded in November 1994 (Shearer, 1995), however, and such variability is a feature of the climate at Cass. Rainfall during winter was relatively low compared with that recorded by Shearer (1995) and Adkins (1997), and did not differ markedly from that recorded in January and February.

Middle Bush Stream

Middle Bush Stream is a small, first order stream on the south side of Cass Hill (Fig. 2.1). The stream arises from a constant temperature (6°C) spring at about 820 m a.s.l. and flows down a steep sided valley supporting mixed scrub, before entering a stand of mountain beech about 450 m downstream (Winterbourn, 1977). On leaving the beech forest, the stream flows through tussock grassland and mixed scrub (mainly matagouri (*Discaria toumatou*) and *Coprosma* sp.) until it reaches Grasmere Stream (Winterbourn, 1977). Although the stream is spring-fed, its discharge is strongly influenced by precipitation, and the distance it flows above ground varies temporally. The extent of bed drying is unpredictable and differs from year to year. McCammon (1978) reported that the grassland reach of Middle Bush Stream was usually dry from just below the beech forest, whereas in recent years drying has been less extensive. The lower portion (~80 m) of Middle Bush Stream dried up for several months during my study, and research focussed on this intermittently flowing zone.

Study sites

Five study sites that varied in flow regime and to an extent, riparian vegetation, were established along a 650 m section of Middle Bush Stream (Fig. 2.3). Site 1, the uppermost site, was situated in the forested section of stream (Plate 2.1a), Site 2 was approximately 50m below the forest in tussock grassland (Plate 2.1b), and Sites 3, 4 and 5 (also in tussock grassland) were located further downstream (Plates 2.1c, 2.2a, b & c). Sites 1-4 were similar, with well defined, stony stream channels that were about

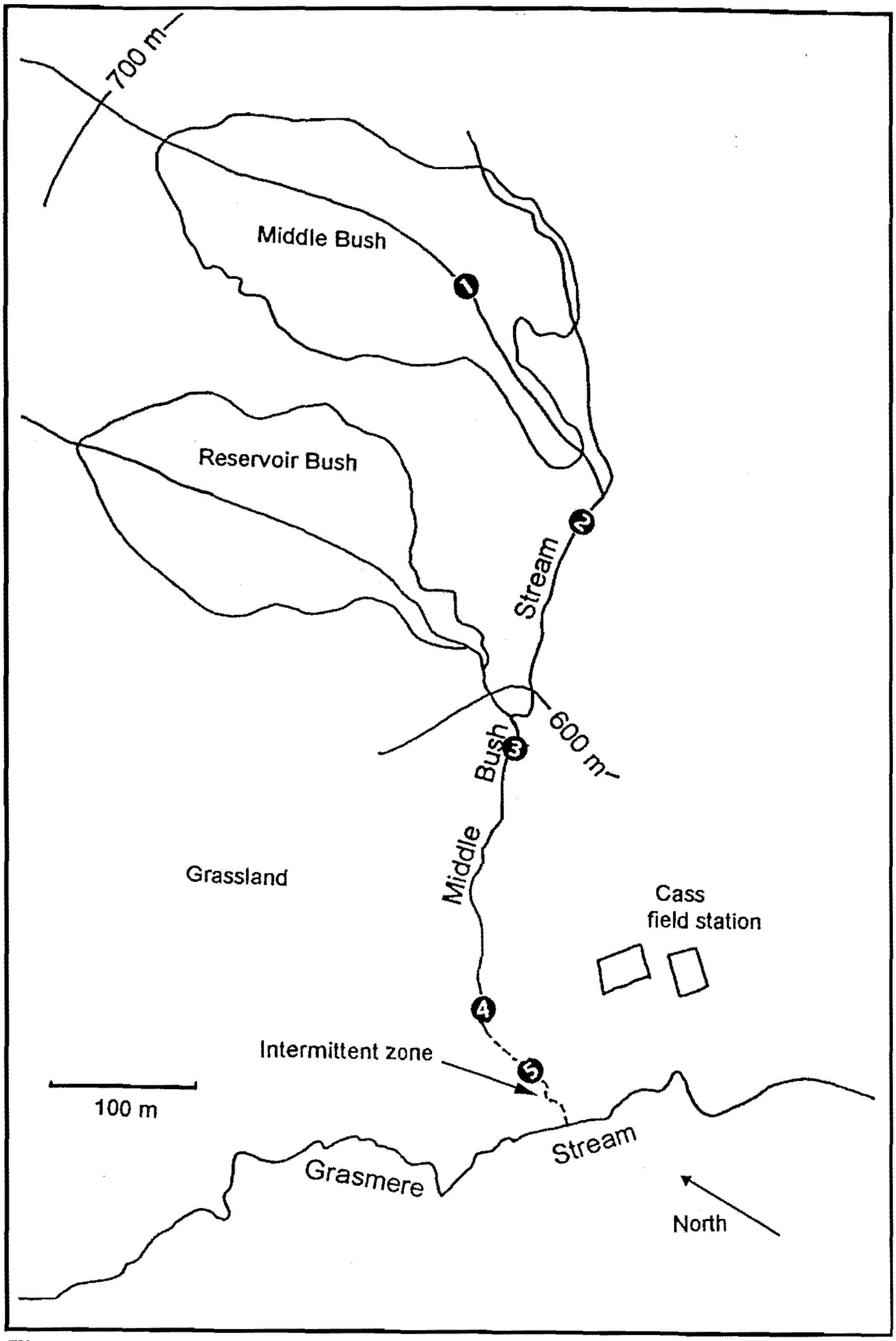


Fig. 2.3 Location of study sites along Middle Bush Stream (represented by the numbers 1 to 5).

c

Plate 2.1 **a)** Site 1 (forested site).

b) Site 2.

c) Site 3 (with hyporheic samplers).

Plate 2.2 **a)** Site 4.

b) Site 5: surface water present (with hyporheic samplers).

c) Site 5: surface water absent (with hyporheic samplers).

1 m wide, while the intermittently flowing Site 5 was poorly channelised and more variable in width.

Flow characteristics

Flow conditions were monitored continuously along the lower course of Middle Bush Stream, so that the onset and duration of channel drying could be established. A series of electronic temperature loggers (HOBO® temp; Onset Corp.) that recorded temperature every 30 minutes were installed at the lower two study sites (Sites 4 and 5) for monthly periods throughout the year. Five loggers were placed in the channel and one was positioned in the shade beside the channel about 1.5 m above the ground. Periods of channel drying were identified by comparing temperature in the stream channel with that beside the stream channel.

The flow regime at Site 5 during the 12 month study period is shown in Fig. 2.4. Channel drying began at Site 5 in January 1997 when surface water disappeared on several occasions towards the end of the month. My on-site observations indicated that the extent of drying varied on a daily basis, with some sections of the bed drying during the day and rewetting at night. The stream bed at Site 5 was dry continually from early February until 20 April 1997, when flow resumed (Fig 2.5). Although flow declined greatly at Site 4, the stream bed remained covered with water throughout the study period. All other sites remained wet throughout the study.

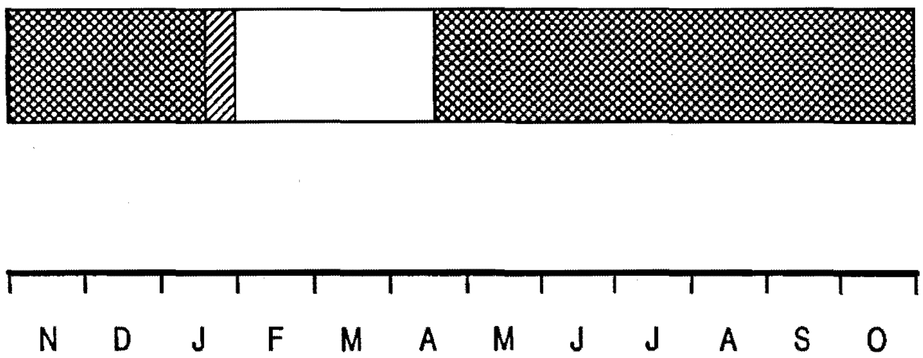


Fig. 2.4 Flow regime from 1 November 1996 - 31 October 1997 at Site 5. ▩ = stream bed wet, ▨ = stream bed intermittently wet and dry on a daily basis, and ☐ = stream bed dry.

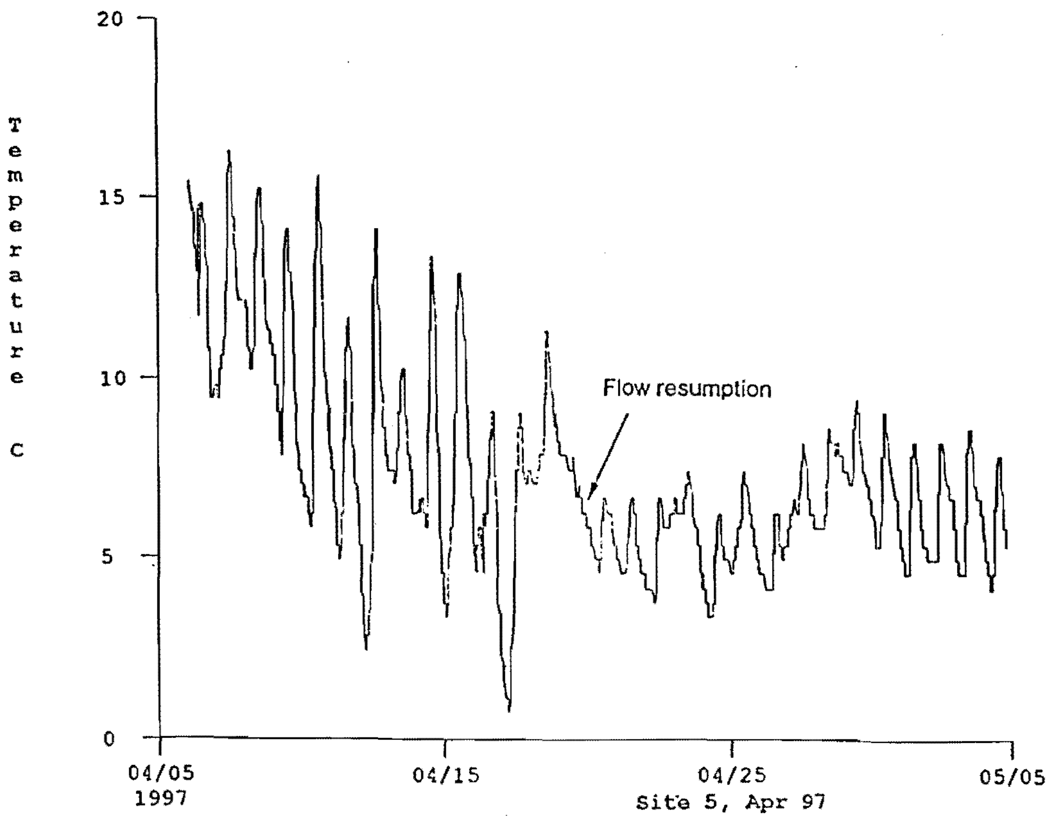


Fig. 2.5 Temperature data from the stream bed at Site 5 in April, 1997. Resumption of flow reduced temperature extremes.

CHAPTER THREE

BENTHIC FAUNA

Introduction

Rivers and streams of the Cass region and their invertebrate faunas have been the subject of several studies (for example Death, 1991; Shearer, 1995; Adkins, 1997) and Middle Bush Stream has been the site of more studies than any other (for example, Winterbourn & Davis, 1976; Winterbourn, 1976, 1977, 1978, 1982; McCammon, 1978, and Adkins, 1997). Most studies have focused on the forested section of Middle Bush Stream, however, and very little is known about the invertebrate fauna living in the lower intermittent reach which flows through tussock grassland.

The invertebrate community in the forested section is dominated by Plecoptera (particularly *Spaniocerca zelandica*, *Zelandobius* spp., and *Austroperla cyrene*), Ephemeroptera (*Deleatidium* spp.), Chironomidae and a diverse trichopteran fauna (including *Hydrobiosella stenocerca*, *Zelandopsyche ingens*, *Philorheithrus agilis* and *Olinga feredayi*) (Winterbourn, 1977, 1978, 1982). Notable absentees from this forest stream are shrimps, molluscs, amphipods, *Coloburiscus humeralis* (Ephemeroptera), *Triplectides* and *Helicopsyche* (Trichoptera) (Winterbourn, 1977).

In addition to the forest stream work, Cowie and Winterbourn (1979) studied invertebrate faunas associated with 3 mosses in the first 30 metres of Middle Bush Stream. Of the 44 taxa identified there, two appeared to be restricted to the moss habitat (*Zelolessica cheira* and *Conuxia gunni*), the remainder also inhabiting stones in the headwaters and further downstream.

In this chapter I report the results of a further investigation of the benthic invertebrate fauna of Middle Bush Stream, focusing more specifically on the lower reach below the forest where the stream flows through tussock grassland, and exhibits a variable degree of intermittent flow. I set out to address three questions:

1) What invertebrates comprise the benthic fauna of Middle Bush Stream, particularly the lower reach that flows through tussock grassland?
2) Does the composition and abundance of the fauna change seasonally?
3) Does faunal composition vary among the five study sites in and below the forest?

Methods

Fieldwork was carried out between November 1996 and October 1997. Four Surber samples ($0.025m^2$; ~0.5 mm mesh) were collected from shallow riffles at Sites 3 and 5 each month (excluding Site 5 in March and April due to drying of the stream bed), and from all five sites on four occasions (November, February, June and September). The substratum within the Surber frame was disturbed to a depth of about 10 cm.

Samples were preserved in 95% methylated spirits in the field, and were sorted and identified in a Bogorov tray at 60X magnification. Identifications of most taxa were made to the lowest taxonomic level possible using keys and descriptions published by McFarlane (1951), Cowley (1978), Winterbourn and Mason (1983), Winterbourn and Gregson (1989) and McLellan (1991). However, most Diptera including Chironomidae were identified only to family and Oligochaeta to class.

Data were analysed statistically for differences in abundance between sites and months using the non-parametric Kruskal-Wallis test (α=0.05; Zar, 1984).

Results

Fifty-nine taxa were collected from benthic samples in Middle Bush Stream over the 12 month period of which 53 were insects. The Trichoptera was the most diverse order with 25 recognisable taxa, while 7 Plecoptera, 4 Ephemeroptera, 11 Diptera and 5 Coleoptera taxa were also found. Non-insect groups collected were Oligochaeta, Ostracoda (*Darwinula* sp.),

Table 3.1 List of taxa collected in benthic samples at each site.

	Site				
	1	2	3	4	5
Trichoptera					
Beraeoptera roria			+		
Helicopsyche sp.				+	+
Hudsonema aliena		+	+	+	+
Hudsonema amabilis			+	+	+
Oeconesus maori		+	+	+	+
Olinga spp.*	+	+	+	+	+
Oxyethira albiceps			+	+	+
Philorheithrus agilis	+	+	+	+	+
Pycnocentrella eruensis					+
Pycnocentria evecta	+	+	+	+	+
Zelandopsyche ingens	+	+	+	+	
Aoteapsyche sp.				+	
Aoteapsyche colonica				+	+
Costachorema sp.		+	+	+	
Costachorema psaroptera			+		
Edpercivalia maxima	+	+	+	+	+
Hydrobiosella stenocerca	+		+		+
Hydrobiosis spp.	+	+	+	+	+
Hydrobiosis clavigera			+	+	+
Hydrobiosis parumbripennis			+	+	+
Hydrobiosis spatulata	+		+	+	+
Hydrochorema crassicaudatum	+	+	+	+	
Hydrochorema tenuicaudatum		+			
Polyplectropus sp.			+		
Psilochorema spp.			+	+	+
Plecoptera					
Austroperla cyrene		+	+	+	
Cristaperla fimbria	+	+			+
Spaniocerca zelandica	+	+	+	+	+
Stenoperla prasina		+			
Zelandobius spp.	+	+	+	+	+
Zelandobius pilosus			+	+	+
Zelandoperla sp.		+			
Ephemeroptera					
Austroclima jollyae				+	
Coloburiscus humeralis			+	+	+
Deleatidium spp.	+	+	+	+	+
Nesameletus sp.	+	+	+	+	+
Diptera					
Aphrophila neozelandica			+		
Austrosimuliium sp.	+	+	+	+	+
Ceratopogonidae	+				+
Chironomidae	+	+	+	+	+
Eriopterini sp. 1	+	+	+	+	+
Eriopterini sp. 2	+	+	+	+	

Table 3.1 (continued)

	Site				
	1	2	3	4	5
Hexatomini	+		+	+	+
Limonia sp.				+	+
Muscidae	+		+	+	+
Nothodixa sp.	+	+	+	+	+
Stratiomyidae	+	+	+		
Oligochaeta	+	+	+	+	+
Coleoptera					
Elmidae	+	+	+	+	
Hydraenidae	+	+	+	+	+
Hydrophilidae			+		
Ptilodactylidae	+				
Scirtidae	+	+	+		+
Mollusca					
Potamopyrgus antipodarum			+	+	+
Crustacea					
Darwinula sp.	+	+	+	+	+
Acarina		+	+	+	
Nematomorpha					
Gordiidae					+
Platyhelminthes					
Neppia montana	+	+	+	+	+
Mecoptera					
Nannochorista philpotti			+		

*Both *Olinga feredayi* and *Olinga jeanae* may occur in Middle Bush Stream, however, due to difficulties distinguishing the two at the larval stage, I have considered both species together in this study.

Mollusca (*Potamopyrgus antipodarum*), Platyhelminthes (*Neppia montana*), Nematomorpha (*Gordius* sp.) and Acarina (Table 3.1).

Downstream sites (3, 4 and 5) had greater species richness than upstream sites, largely as a result of greater trichopteran diversity (Table 3.2). Taxa that occurred at downstream sites 3, 4 and 5 and not at Sites 1 and 2 included the caddisflies *Hudsonema amabilis*, *Oxyethira albiceps*, *Hydrobiosis clavigera*, *Hydrobiosis parumbripennis* and *Psilochorema* spp., the stonefly *Zelandobius pilosus* and the mayfly *Coloburiscus humeralis*. Some taxa occurred at all 5 sites. They included *Olinga* spp., *Philorheithrus agilis*, *Pycnocentria evecta* and *Edpercivalia maxima* (Trichoptera), *Spaniocerca zelandica* (Plecoptera), *Deleatidium* spp. and *Nesameletus* sp. (Ephemeroptera), *Austrosimuliium* sp., *Nothodixa* sp. and Chironomidae (Diptera), and Hydraenidae (Coleoptera). Only one taxon (Ptilodactylidae) was found solely at the forested Site 1 (Table 3.1). Invertebrate community composition at the five sites is compared in Fig. 3.1.

Table 3.2 Total number of invertebrate taxa collected from each site (all dates combined).

Taxa	Site 1	Site 2	Site 3	Site 4	Site 5
Trichoptera	9	11	20	19	17
Plecoptera	3	6	4	4	4
Ephemeroptera	2	2	3	4	3
Diptera	9	6	9	8	8
Coleoptera	4	3	4	2	2
Mecoptera	0	0	1	0	0
Other*	3	4	5	5	5
Total	30	32	46	42	39

*"Other" refers to non-insect groups (Oligochaeta, Mollusca, Nematomorpha, Platyhelminthes, Crustacea and Acarina).

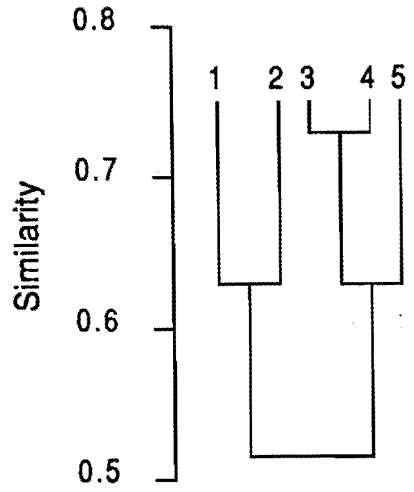


Fig. 3.1 Cluster analysis of Sites 1-5 using presence/absence data for benthic communities.

Chironomidae and *Deleatidium* spp. were the most abundant insect taxa at each site, and together comprised between 72.1 and 84.4% of insects taken from each site. *Zelandobius* spp. (excluding *Zelandobius pilosus*) were also relatively abundant at Sites 1, 2 and 3, but less abundant at Sites 4 and 5, however, *Zelandobius pilosus* was abundant at Site 5. *Austrosimuliium* sp. was also common at the four grassland sites (Table 3.3). The ostracod *Darwinula* sp. and Oligochaeta were also very abundant at most sites, although oligochaetes were poorly represented at Site 2 and ostracods were uncommon at Site 5 (Table 3.4). The mean number of taxa taken at all sites did not differ significantly over time (Fig. 3.2e), and ranged from 9.6 to 12.4.

Mean numbers of invertebrates differed significantly among sites in February, June and September (P=0.019, 0.025 and 0.027, respectively), but no one site had consistently higher invertebrate abundance over all seasons (Fig. 3.3). Mean numbers of invertebrates at each site for the four months combined (Fig. 3.3e), did not differ significantly (P>0.05).

At all 5 sites combined, mean number of invertebrates differed significantly with season (P<0.001) (Fig. 3.2a). Invertebrate abundance was lowest in February and highest in June. The most abundant insect taxa, Chironomidae and *Deleatidium* spp. also differed significantly in abundance in the months sampled (P=0.032 and <0.001, respectively). Both exhibited

Table 3.3 The five most abundant **insect** taxa in order of frequency of abundance at each site, all sampling dates combined. Numbers indicate percentage of total insect numbers.

	Order of abundance									
	1		2		3		4		5	
Site 1	Chironomidae	46.9	*Deleatidium* spp.	28	*Zelandobius* spp.	5.6	*S. zelandica*	3.1	Hydraenidae	2.5
Site 2	*Deleatidium* spp.	44.4	Chironomidae	31	*Zelandobius* spp.	9.0	*Austrosimuliium* sp.	4.1	*Nesameletus* sp.	2.4
Site 3	Chironomidae	52.4	*Deleatidium* spp.	32.0	*Zelandobius* spp.	3.2	*Hydrobiosis* spp.	2.6	*Austrosimuliium* sp.	2.0
Site 4	*Deleatidium* spp.	58.0	Chironomidae	14	*Pycnocentria evecta*	5.9	*Austrosimuliium* sp.	5.7	*Nesameletus* sp. *H. amabilis*	2.4
Site 5	*Deleatidium* spp.	41.6	Chironomidae	35	*Austrosimuliium* sp.	5.4	*Z. pilosus*	3.2	*S. zelandica*	2.7

Table 3.4 The five most abundant taxa in order of frequency of abundance at each site, all sampling dates combined. Numbers indicate percentage of total invertebrate numbers.

	Order of abundance									
	1		2		3		4		5	
Site 1	*Darwinula* sp.	28.0	Chironomidae	23	Oligochaeta	19	*Deleatidium* spp.	13	*Neppia montana*	4.0
Site 2	*Deleatidium* spp.	33.6	Chironomidae	23	*Darwinula* sp.	15	*Zelandobius* spp.	6.8	*Neppia montana*	4.8
Site 3	Chironomidae	44.5	*Deleatidium* spp.	27	Oligochaeta	10	*Darwinula* sp.	3.1	*Zelandobius* spp.	2.8
Site 4	*Deleatidium* spp.	47.5	*Darwinula* sp.	12	Chironomidae	12	Oligochaeta	5.3	*P. evecta*	4.8
Site 5	*Deleatidium* spp.	34.9	Chironomidae	29	Oligochaeta	14	*Austrosimuliium* sp.	4.5	*Z. pilosus*	2.7

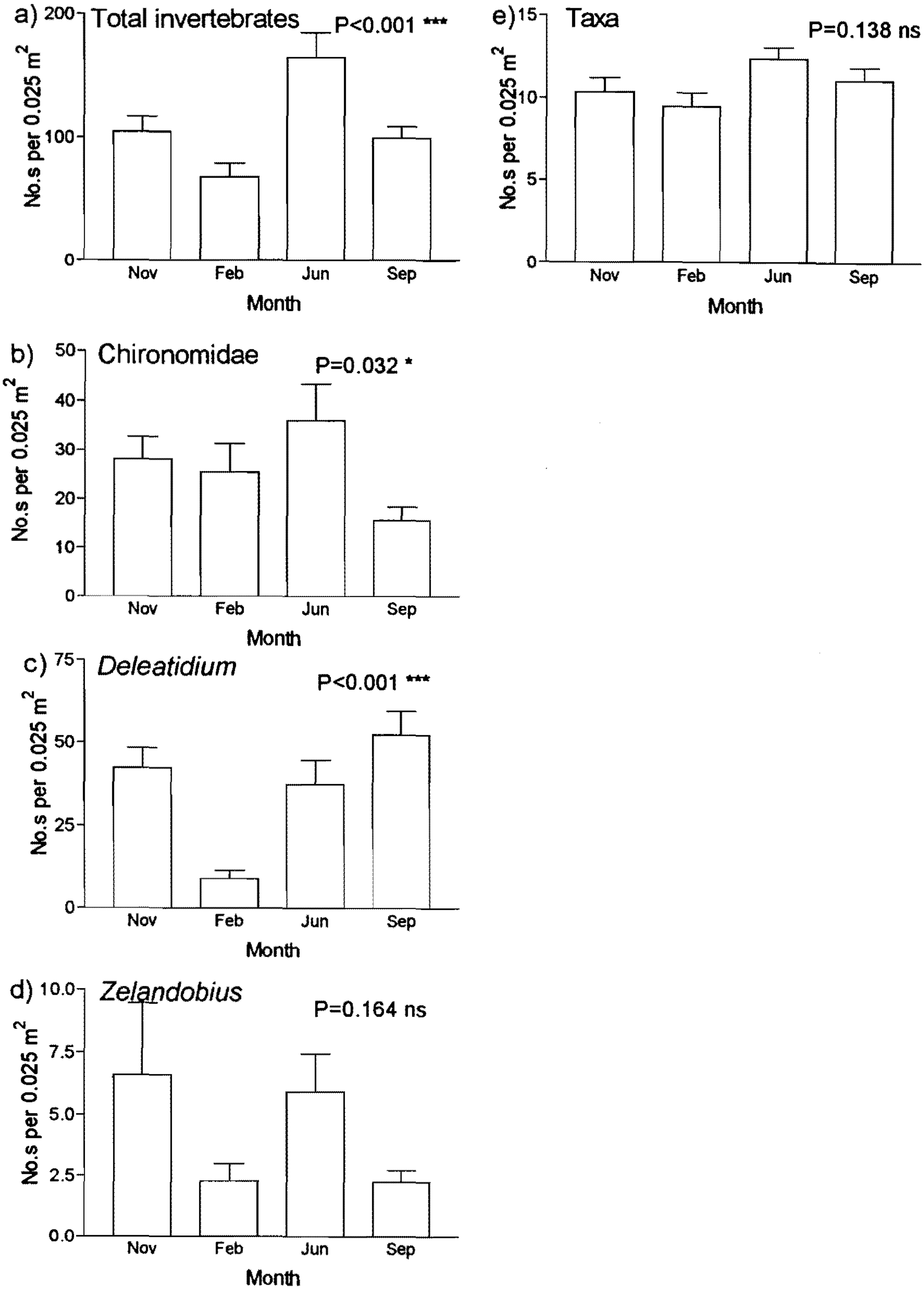


Fig. 3.2 Abundances of a) total invertebrates, b) Chironomidae, c) *Deleatidium* spp., d) *Zelandobius* spp. and e) taxa collected in 4 months (mean ± 1 SE). Note that scale of the y-axis varies. P values are for Kruskal-Wallis analysis of variance among results.

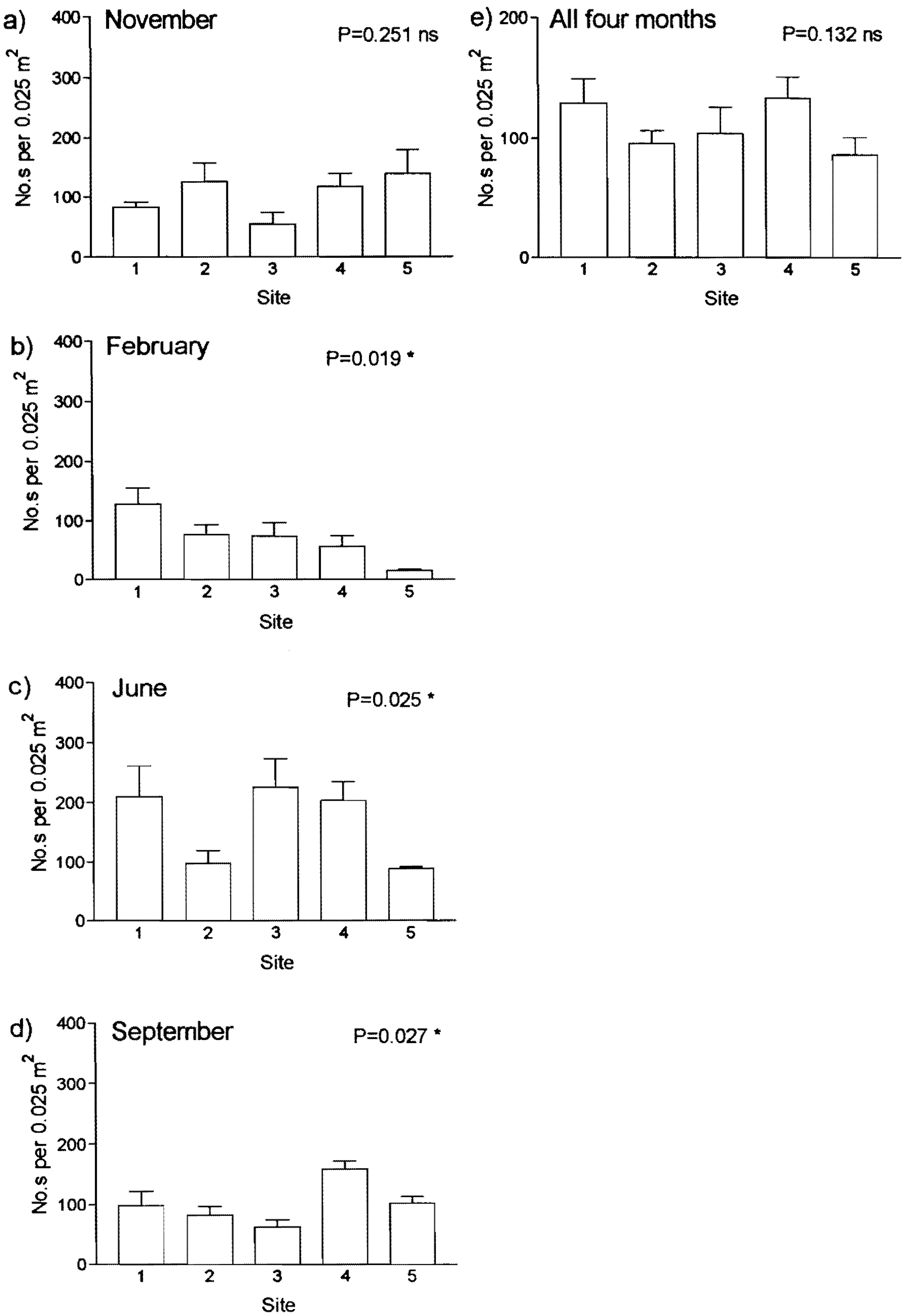


Fig. 3.3 Abundance of invertebrates (mean ± 1 SE) at each site in a) November, b) February, c) June, d) September and e) all four months.

similar declines in abundance in February, followed by increases in June, although *Deleatidium* numbers were greatest in September. Chironomid abundance peaked in June (Fig. 3.2b & c). Mean numbers of *Zelandobius* spp. (including *Z. pilosus*) were also lowest in February and highest in November, although differences among months were not significant ($P>0.05$) (Fig. 3.2d).

When sites were considered individually, seasonal changes in the abundance of total invertebrates, *Deleatidium* spp. and Chironomidae were observed only at the three downstream sites (Table 3.5).

Table 3.5 Summary of non-parametric Kruskal-Wallis comparisons of total invertebrate abundance, *Deleatidium* abundance and abundance of Chironomidae at each site in November, February, June and September. Significant P-values are shown in bold ($P<0.05$).
* = $P< 0.05$, ** = $P< 0.01$, ns = $P> 0.05$.

Seasonal comparison of:	Site	P-value	Summary
Total invertebrates	1	0.0693	ns
	2	0.5011	ns
	3	**0.0336**	*
	4	**0.0179**	*
	5	**0.0271**	*
Deleatidium	1	0.7650	ns
	2	0.2990	ns
	3	**0.0039**	**
	4	**0.0146**	*
	5	**0.0040**	**
Chironomidae	1	0.6487	ns
	2	0.0686	ns
	3	**0.0277**	*
	4	0.7842	ns
	5	**0.0216**	*

Discussion

A diverse invertebrate fauna inhabits Middle Bush Stream, especially in the lower grassland reach, which had greater taxonomic diversity than the forested reach. While all of the sites were dominated by *Deleatidium* spp., Chironomidae, *Darwinula* sp. and Oligochaeta, the faunal assemblage at the lower three sites differed markedly from that associated with the forest. This was principally due to an increase in trichopteran diversity lower in the stream and the appearance of several other taxa (including *Coloburiscus humeralis*, *Potamopyrgus antipodarum* and *Zelandobius pilosus*). In contrast, all but one taxon (Ptilodactylidae) taken from within the forest also occurred in the grassland reach. Despite this distinct change in faunal composition along the stream, total abundance of invertebrates differed little.

The primary reason for these changes seems to be the presence/absence of forest. Sticky trapping (see Chapter 6) indicated that the forest acted as a barrier to many adult caddisfly species, thus preventing them from laying eggs in the forested section of stream. Secondly, changes in the morphology of Middle Bush Stream may be responsible for some of the increased faunal diversity at the downstream sites. The grassland section of stream runs through a valley that becomes progressively more open as it decreases in altitude, and becomes progressively closer to Grasmere Stream, which is a probable source of colonists. Thus, it seems likely that the lower portion of Middle Bush Stream receives colonists from both its upstream, forested reach and Grasmere Stream. If this is so, one would expect the fauna of the lower grassland reach of Middle Bush Stream to comprise elements of the faunas characteristically found in the forest and Grasmere Stream. This hypothesis is addressed in Tables 3.6 & 3.7. Of the 55 taxa found in the grassland reach of Middle Bush Stream, 48 were also found in either the forested reach (18 taxa), Grasmere Stream (11 taxa) or both (19 taxa) (Table 3.6). Comparison of the faunal assemblages in the three environments delineated above (Table 3.7), further emphasises that both the forested reach of Middle Bush Stream and Grasmere Stream are more similar to the grassland reach of Middle Bush Stream than they are to each other. This strongly suggests that faunal composition in the grassland

Table 3.6 List of invertebrates found in the grassland section of Middle Bush Stream and presence/absence of the same species in the forested section of Middle Bush Stream (data from Winterbourn, 1978 & 1982), and Grasmere Stream (data from Death, 1991).

	Forest	Grassland	Grasmere
Trichoptera			
Beraeoptera roria		+	+
Helicopsyche sp.		+	
Hudsonema aliena	+	+	+
Hudsonema amabilis		+	+
Oeconesus maori		+	
Olinga spp.	+	+	+
Oxyethira albiceps		+	+
Philorheithrus agilis	+	+	
Pycnocentrella eruensis		+	
Pycnocentria evecta	+	+	+
Zelandopsyche ingens	+	+	
Aoteapsyche sp.		+	+
Aoteapsyche colonica		+	+
Costachorema sp.		+	
Costachorema psaroptera	+	+	
Edpercivalia maxima	+	+	
Hydrobiosella stenocerca	+	+	
Hydrobiosis spp.	+	+	+
Hydrobiosis clavigera		+	
Hydrobiosis parumbripennis		+	+
Hydrobiosis spatulata	+	+	+
Hydrochorema crassicaudatum	+	+	
Polyplectropus sp.		+	+
Psilochorema spp.		+	+
Plecoptera			
Austroperla cyrene	+	+	
Cristaperla fimbria	+	+	
Spaniocerca zelandica	+	+	
Zelandobius spp.	+	+	+
Zelandobius pilosus		+	
Ephemeroptera			
Austroclima jollyae		+	
Coloburiscus humeralis		+	+
Deleatidium spp.	+	+	+
Nesameletus sp.	+	+	+
Diptera			
Aphrophila neozelandica		+	+
Austrosimuliium sp.	+	+	+
Ceratopogonidae	+	+	+
Chironomidae	+	+	+
Eriopterini sp. 1	+	+	
Eriopterini sp. 2	+	+	
Hexatomini	+	+	
Limonia sp.	+	+	

Table 3.6 (continued)

	Forest	Grassland	Grasmere
Muscidae	+	+	+
Nothodixa sp.	+	+	+
Stratiomyidae	+	+	
Oligochaeta	+	+	+
Coleoptera			
Elmidae	+	+	+
Hydraenidae	+	+	
Hydrophilidae	+	+	
Scirtidae	+	+	+
Mollusca			
Potamopyrgus antipodarum		+	+
Crustacea			
Darwinula sp.	+	+	+
Acarina	+	+	+
Nematomorpha			
Gordius sp.	+	+	
Platyhelminthes			
Neppia montana	+	+	+
Mecoptera			
Nannochorista philpotti	+	+	

Table 3.7 Faunal similarity of the forested section of Middle Bush Stream, the grassland section of Middle Bush Stream and Grasmere Stream using Jaccard's Coefficient of Community and presence/absence data.

Site comparison	Similarity index
Forest v Grassland	0.59
Grasmere v Grassland	0.49
Forest v Grasmere	0.33

reach is influenced by colonists from both of these sources. This issue is discussed further in Chapter 6.

While no seasonal variation in total invertebrate abundance occurred at the upper two sites, the three downstream sites exhibited significant decreases in abundance in February, and subsequent increases in June. Seasonal changes in abundance of the two dominant insect taxa, *Deleatidium* spp. and Chironomidae were primarily responsible for this trend. While the decrease in invertebrate abundance at Site 5 in February could be attributed to drying of the stream bed, the decreased abundances at Sites 3 and 4 were more likely to have been a consequence of the life histories of the animals involved. Emergence of adult *Deleatidium* spp. commonly occurs in late summer as shown by sticky trap collections made in this study (Chapter 6), and might be expected to result in a decrease in abundance of larvae, as reported by Greig (1976) for *Deleatidium* in Lake Grasmere. The increased abundance of larvae seen in June can also be attributed to life history events: egg laying and subsequent larval growth resulting in rapid population growth in autumn.

The upper two sites did not show comparable seasonal trends in total invertebrate abundance, despite being dominated by members of the same two taxa, *Deleatidium* and Chironomidae. This may have been due to different species being included in these two taxonomic groups. My collections indicate that several *Deleatidium* species inhabit Middle Bush Stream, however, accurate identification to species level is has proved extremely difficult and frustrating for larvae of all sizes. Death (1991) identified *Deleatidium myzobranchia* as the common mayfly species in the forested section of Middle Bush Stream, whereas both *D. myzobranchia* and *D. vernale* may be present at the downstream sites. It is possible that the two species have different life history patterns as do several *Deleatidium* species in the Waitakere River (Towns, 1983b), and if so, seasonal variation in *Deleatidium* larval density at the grassland sites could be a consequence of the presence of *D. vernale* at those sites. In contrast, the lack of seasonal variation within the forest may be due to the absence of this species and the presence of the less seasonal *D. myzobranchia* (Towns, 1983b).

The lack of seasonal variation in abundance of larval Chironomidae at the forest site compared to the grassland site may also be due to differences in species composition at different sites along the stream. At least eight chironomid taxa were identified from Middle Bush Stream samples during the course of my study, including *Paucispinigera approximata* and a species of *Polypedilum* (Chironominae), *Maoridiamesa harrisi* and nr. *Limaya* (of Schakau, 1993) (Diamesinae), *Cricotopus* sp., a second Orthocladiinae species, and two species of Tanypodinae. However, as with *Deleatidium* their occurrences in space and time were not monitored during the study.

In summary, it seems clear that the most pronounced differences in stream assemblage composition were related to the presence or absence of forest. Forests typically moderate climatic extremes, and it is possible that they are inhabited by more species with less seasonal life histories than are the more exposed grasslands. Furthermore, life histories of individual species may also vary at forest and grassland sites, resulting in different overall patterns of abundance and seasonality in the two environments.

CHAPTER FOUR

INVERTEBRATE DRIFT

Introduction

Invertebrate drift is a widespread and well documented phenomenon in lotic ecosystems (review articles by Waters, 1972; Müller, 1974 and Brittain & Eikeland, 1988). It plays an important role in the redistribution of stream benthos (Brittain & Eikeland, 1988), and the importance of drift as a mechanism for repopulating denuded areas of stream bed in permanently flowing streams has been investigated in many studies (for example Watson, 1971; Williams & Hynes, 1976; Townsend & Hildrew, 1976; Bird & Hynes, 1981; Kramer, 1982; Bergey & Ward, 1989; Mackay, 1992). These studies indicate that drift is commonly a major recolonising mechanism: Townsend & Hildrew (1976) for example found that drift was responsible for 82 % of the colonisation of denuded areas of streambed in an English stream, and Williams & Hynes (1976) found drift to be the most important of four colonistion pathways (drift, upstream movement, vertical migration from the substrate and oviposition) considered in a Canadian stream. A very similar percentage contribution by drift was obtained by Kramer (1982) in an almost identical study in the South Branch of the Waimakariri River, just outside Christchurch.

Drift may also be an important source of colonists in temporary and intermittent streams. In intermittent streams with perennially flowing upper reaches, drift is commonly the primary source of colonists (McArthur & Barnes, 1985 and Paltridge *et al.*, 1997). It has also been considered the main recolonising mechanism in several other studies, in which denuded reaches of substrate receive water from more permanent lotic waters; for instance in a reclaimed coal strip mine (Gore, 1979, 1982), and following rewatering of previously dry channels of a braided river (Sagar, 1983). Other studies of temporary / intermittent streams have found alternative sources of colonists (e.g., oviposition) to be of primary importance (Harrison, 1966; Hynes, 1975; Williams, 1977 and Gray & Fisher, 1981), although drift may still provide a means of dispersing clumped individuals from oviposition sites and pools (Williams, 1977; Gray & Fisher, 1981; Paltridge *et al.*, 1997), or for redistributing animals emerging from refuges in the stream bed (Williams, 1977).

The extent of drift in streams, and therefore its potential importance as a source of recolonists, is influenced by many interacting factors. Diel and seasonal variations in drift density are common (for example Waters, 1972; Brittain & Eikeland, 1988; Benson & Pearson, 1987; Rincón & Lobón, 1997; O'Hop & Wallace, 1983; McLay, 1968), and drift is also affected by changes in discharge (Minshall & Winger, 1968; Townsend & Hildrew, 1976; Bird & Hynes, 1981; McArthur & Barnes, 1985), temperature and water chemistry (Brittain & Eikeland, 1988). Biotic factors, including the density of benthic invertebrates (Pearson & Kramer, 1972; Brittain & Eikeland, 1988) and their developmental stage (Waters, 1972; Pearson & Kramer, 1972; Muller, 1974; Bird & Hynes, 1981; O'Hop & Wallace, 1983), and the presence of predators, such as fish (Flecker, 1992; Forrester, 1994) may also influence both the amount and timing of drift.

I hypothesised that drift from the perennially flowing upstream reach of Middle Bush Stream would be of considerable importance in the recolonisation of the lower intermittent zone. The permanently flowing section of the stream harbours a diverse and abundant invertebrate community (Chapter 3), and dispersal from this source is likely to occur during rewetting of the lower reach. My research focused on this hypothesis by addressing the following questions:

1) Does downstream drift provide a source of colonists to the downstream reach:
    a) when water returns to the stream?
    b) during continuous flow?
2) Does the importance of downstream drift as a colonisation method vary seasonally?

Methods

Drift samples were collected over a 24 hour period from each site on a monthly basis (excluding Site 5 in February, March and April when the stream bed was dry). Drift traps consisted of three nets (105 x 55 mm aperture, 1 m net length, 0.25 mm mesh) positioned approximately 30 mm apart on a metal frame, enabling three replicate samples to be collected from each site on each occasion (Plate 4.1). Metal stakes were driven into the stream bed to hold the samplers in place. A plastic container attached to the end of each drift net could be unscrewed to allow sample removal. When the samplers were installed each month, flow velocity (OOS-PC1 flow meter) and water depth were measured at the net entrance. After 24 hours, invertebrate samples were removed by unscrewing the containers at the ends of the nets and washing each sample into a hand-held stream net of the same mesh size. The contents were preserved in 95% methylated spirits and later sorted in a Bogorov tray under 60X magnification. Invertebrates were identified as described in Chapter 3.

Drift densities were calculated using the following formula:

$$\begin{array}{c}\text{Drift density}\\ \text{(Number of invertebrates}\\ \text{per 100 m}^3\text{ water)}\end{array} = \frac{(N)\,(100)}{(t)\,(W)\,(H)\,(V)\,(3600\text{ s/h})}$$

where N = number of invertebrates, t = time the net was in the stream (hours), W = width of net (m), H = height of net (m) and V = water velocity (m/s) (Allan & Russek, 1985).

Proportions of the benthos in the drift per m^3 in November, February, June and September were calculated using the following equation:

$$\%\text{ of benthos in the drift} = \frac{xD.100}{X\text{-}xD}$$

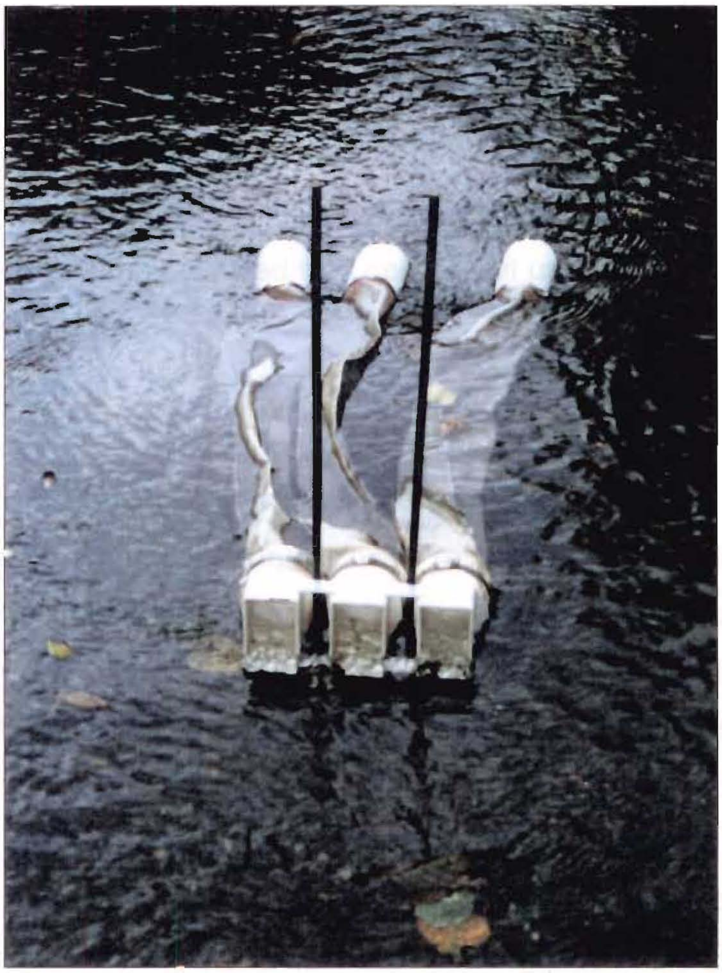


Plate 4.1 Drift sampler: each net has a 105 x 55 mm aperture, and a length of 1 m.

where x = mean number of animals in drift per m^3, X = mean number of animals on streambed per m^2 and D = Depth of stream in metres at the sampling point (Elliott, 1967).

Data were analysed statistically using the non-parametric Kruskal-Wallis test to compare differences in drift abundance and density between sites and months. Dunn's Multiple Comparison *a posteriori* test was used to determine where significant differences occurred among treatments (Zar, 1984). Spearman's rank correlation coefficients were calculated to assess the relationship between flow velocity and the proportion of the benthos in the drift over time. Cluster analysis of the sites using presence / absence data for all drift fauna collected was carried out using Jaccard's Coefficient of Community index.

Results

A total of 26 578 animals comprising 65 taxa were captured from the drift (Table 4.1). The drift community closely resembled that of the benthos, although, I also found ten taxa that were not taken in benthos samples (*Triplectides obsoleta*, *Tiphobiosis* sp., *Pycnocentria sylvestris, Acroperla spiniger, Halticoperla viridans, Oniscigaster distans, Zelandotipula* sp., *Kempynus* sp., and single species of Sciomyzidae and Dytiscidae) (Table 4.1 & 3.1). Taxonomic composition of the drift fauna at Sites 1 to 5 differed, with some taxa drifting only at the downstream sites (3, 4 and 5). They included *Helicopsyche* sp., *O. albiceps*, *H. clavigera, H. parumbripennis, Polyplectropus* sp., *C. humeralis* and *P. antipodarum.* In contrast, *P. sylvestris, Stenoperla prasina, Zelandotipula* sp. and Elmidae only occurred in the drift at upstream Sites 1 and 2. A few taxa that were taken only from upstream sites (1 and 2) or downstream sites (3, 4 and 5) in the benthic samples were more widespread in the drift, and included *Aoteapsyche* sp., *Costachorema* spp., *Psilochorema* spp., *Z. pilosus, Zelandoperla* sp., *Austroclima jollyae, Limonia* sp. and *Nannochorista philpotti.* Relative similarity of the drift faunas at the five sites as indicated by presence / absence data is illustrated in Fig. 4.1. Two clusters are apparent, one

Table 4.1 List of taxa collected in drift samples at each site.

	Site				
	1	2	3	4	5
Trichoptera					
Beraeoptera roria				+	+
Helicopsyche sp.					+
Hudsonema aliena	+	+	+	+	+
Hudsonema amabilis	+			+	+
Oeconesus maori	+	+	+	+	
Olinga spp.	+	+		+	+
Oxyethira albiceps			+	+	+
Philorheithrus agilis	+	+			
Pycnocentria evecta	+	+	+	+	+
Pycnocentria sylvestris	+	+	+		
Triplectides obsoleta				+	
Zelandopsyche ingens	+	+	+	+	+
Aoteapsyche spp.	+	+			
Aoteapsyche colonica		+	+	+	+
Costachorema sp.	+	+	+	+	+
Costachorema psaroptera	+	+	+	+	+
Edpercivalia maxima	+	+	+	+	+
Hydrobiosella stenocerca	+	+	+	+	+
Hydrobiosis spp.	+	+	+	+	+
Hydrobiosis clavigera				+	+
Hydrobiosis parumbripennis			+	+	+
Hydrobiosis spatulata	+	+	+	+	+
Hydrochorema crassicaudatum		+		+	
Hydrochorema tenuicaudatum	+				
Polyplectropus sp.				+	+
Psilochorema spp.	+	+	+	+	+
Tiphobiosis sp.	+	+	+		+
Plecoptera					
Acroperla spiniger		+			+
Austroperla cyrene			+		+
Cristaperla fimbria	+			+	
Halticoperla viridans	+				
Spaniocerca zelandica	+	+	+	+	+
Stenoperla prasina	+	+			
Zelandobius spp.	+	+	+	+	+
Zelandobius pilosus	+	+	+	+	+
Zelandoperla sp.	+	+	+	+	+
Ephemeroptera					
Austroclima jollyae		+	+	+	+
Coloburiscus humeralis				+	+
Deleatidium spp.	+	+	+	+	+
Nesameletus sp.	+	+	+	+	+
Oniscigaster distans		+		+	+
Diptera					
Austrosimuliium sp.	+	+	+	+	+
Chironomidae	+	+	+	+	+

Table 4.1 (continued)

	Site 1	2	3	4	5
Eriopterini sp. 1		+		+	
Eriopterini sp. 2	+	+		+	+
Limonia sp.	+	+	+	+	+
Muscidae	+	+	+	+	+
Nothodixa sp.	+	+	+	+	+
Paradixa sp.					+
Sciomyzidae				+	
Stratiomyidae			+		+
Zelandotipula sp.	+	+			
Oligochaeta	+	+	+	+	+
Coleoptera					
Dytiscidae					+
Elmidae	+	+			
Hydraenidae	+	+	+	+	+
Hydrophilidae	+	+	+	+	+
Scirtidae	+	+	+	+	+
Mollusca					
Potamopyrgus antipodarum				+	+
Crustacea					
Darwinula sp.	+	+	+	+	+
Acarina	+	+	+	+	+
Nematomorpha					
Gordius sp.	+	+	+	+	+
Platyhelminthes	+	+	+	+	+
Mecoptera					
Nannochorista philpotti	+	+	+		+
Neuroptera					
Kempynus sp.	+		+		

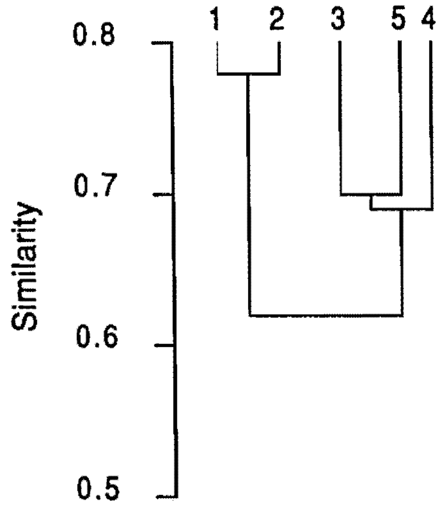


Fig. 4.1 Cluster analysis of Sites 1-5 using presence/absence data from all drift samples.

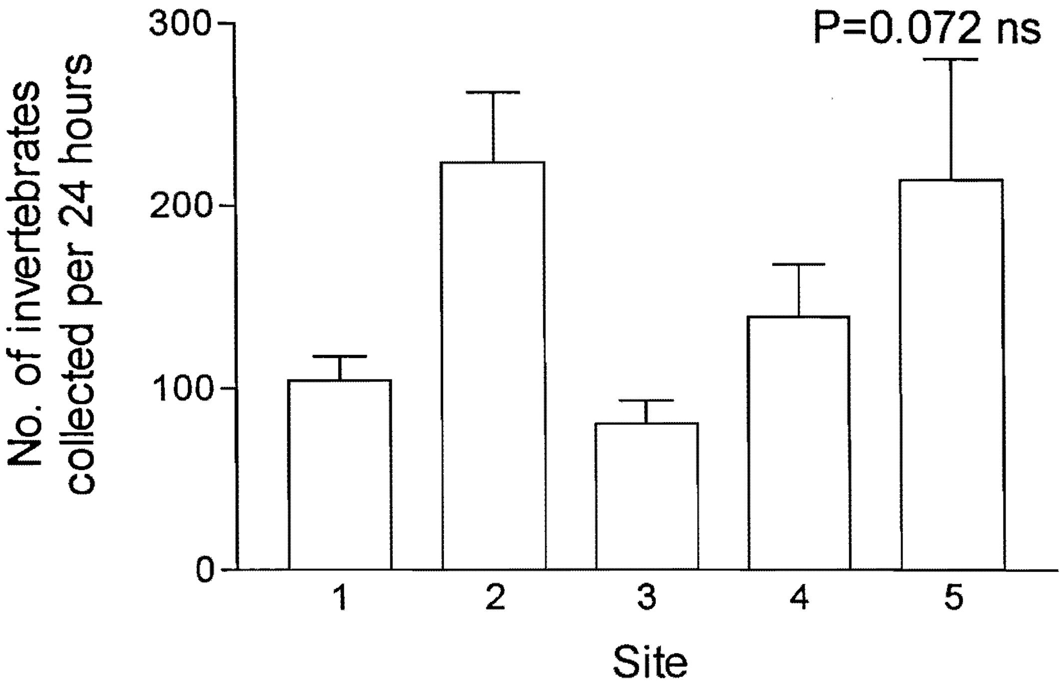


Fig. 4.2 Abundance of drifting invertebrates at each site (mean ± SE) based on data from all months combined. P value refers to outcome of Kruskal-Wallis test.

Table 4.2 The five most abundant drifting taxa in order of abundance at each site, all sampling dates combined.

	Order of abundance				
	1	2	3	4	5
Site 1	*S. zelandica*	Chironomidae	*Deleatidium* spp.	*Z. ingens*	Hydraenidae
Site 2	Chironomidae	*Deleatidium* spp.	*S. zelandica*	*Z. ingens*	*Zelandobius* spp.*
Site 3	Chironomidae	*Deleatidium* spp.	*S. zelandica*	*Austrosimuliium* sp.	*H. aliena*
Site 4	*Deleatidium* spp.	Chironomidae	*H. aliena*	*Austrosimuliium* sp.	*P. evecta*
Site 5	*Deleatidium* spp.	Chironomidae	*Austrosimuliium* sp.	*S. zelandica*	*H. aliena*

* excluding *Z. pilosus*

incorporating the two upstream sites (Sites 1 and 2) and the other the three downstream sites (Sites 3, 4 and 5).

Deleatidium spp., Chironomidae and *Spaniocerca zelandica* were the most abundant drifting taxa at each site, except at Site 4 where *S. zelandica* was poorly represented (Table 4.2). *Zelandopsyche ingens* was abundant in the drift at Sites 1 and 2 but was less common at Sites 3, 4 and 5. In contrast, *Austrosimuliium* sp. and *Hudsonema aliena* were common drifters at the lower three sites but were not found at the two upstream sites. Despite differences in taxonomic composition and relative abundances of taxa at each site, total numbers of invertebrates taken from the drift varied little along the stream, and did not differ significantly among sites (Fig. 4.2).

Drift densities (numbers of individuals per 100 m^3 of water) varied between sites and from month to month (Fig. 4.3). In general, drift density was high in spring and/or summer, and low in autumn and winter. However, densities varied between sites and were generally higher at Sites 1 and 2. In February, March and April when flow velocity was negligible at Sites 3 and 4, large numbers of animals were still caught in drift samplers on occasions (for instance 1081 individuals at Site 4 in April). These invertebrates could not have been drifting due to the lack of flow, and must have crawled or swum into the traps. In May (15 days after rewetting) drift density differed little among sites (Fig. 4.4), and remained low at Site 5 (Fig. 4.5).

Absolute abundance of invertebrates in the drift differed significantly from month to month (Fig. 4.6), and generally conformed with seasonal patterns in drift density. Peak drift abundances occurred in summer (November to February) and low abundances were collected in autumn and winter (March to July). Numbers increased significantly in late-winter and spring (August to October) (Fig. 4.6).

Results obtained at Site 4, provide the best indication of the composition and abundance of the fauna drifting into the intermittently flowing Site 5 under various flow conditions. In December when flow was continuous at Sites 4 and 5, *Deleatidium* spp., Chironomidae and *Austrosimuliium* sp. dominated the drift numerically at Site 4, and mean

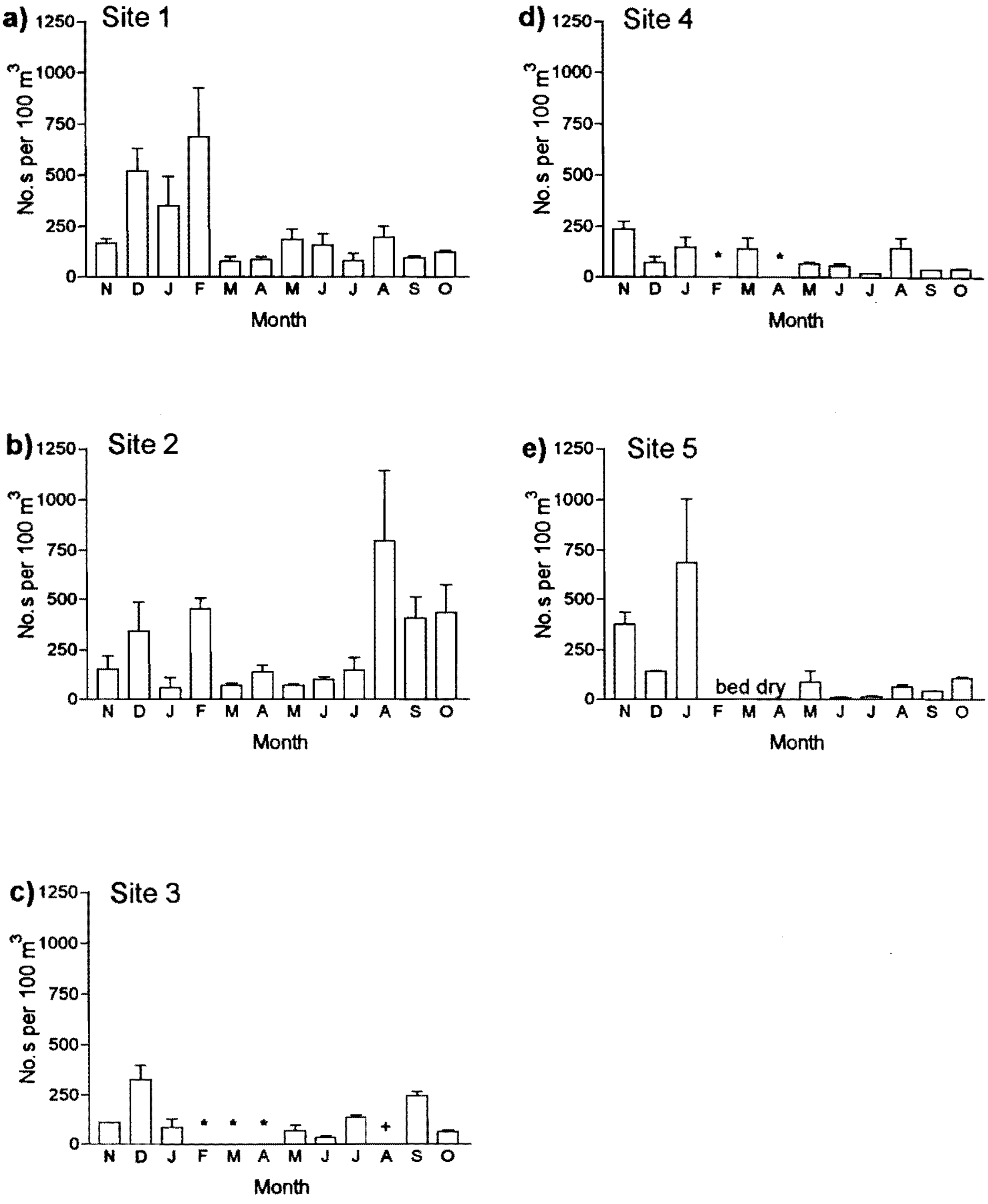


Fig. 4.3 Drift densities (number of invertebrates per m^3 water) over the 12 month sampling period at a) Site 1, b) Site 2, c) Site 3, d) Site 4 and e) Site 5. * denotes samples collected during nil flow that contained invertebrates and therefore had drift densities of ∞, + denotes no sample taken.

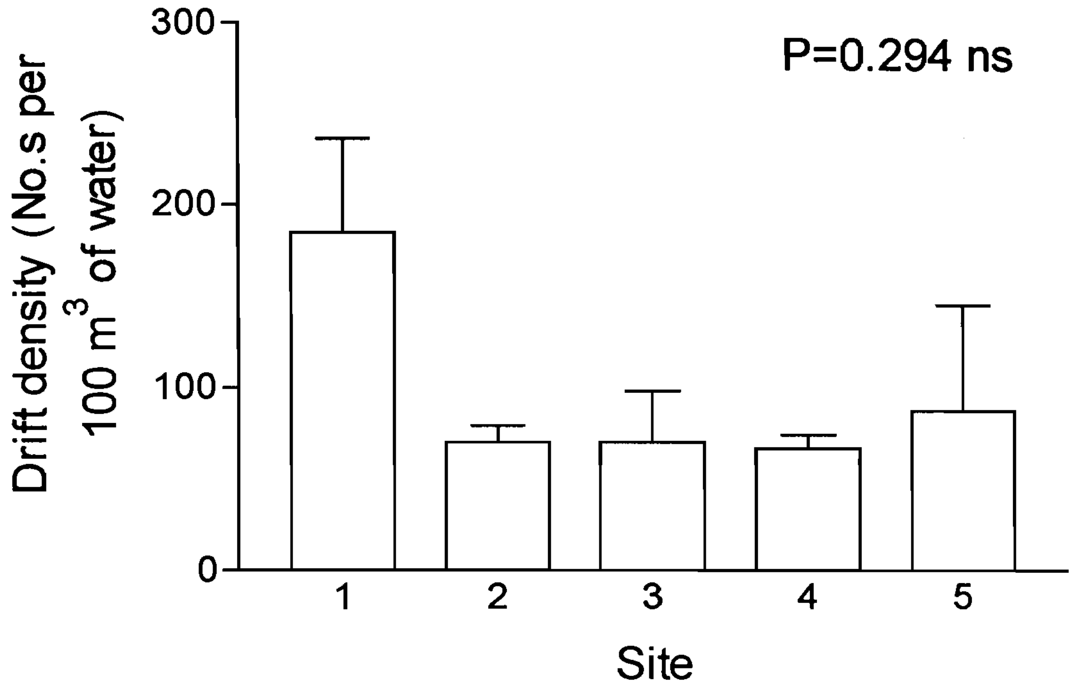


Fig 4.4 Drift density at each site in May (mean ± SE), 15 days after rewetting occurred at Site 5. P value refers to outcome of Kruskal-Wallis test.

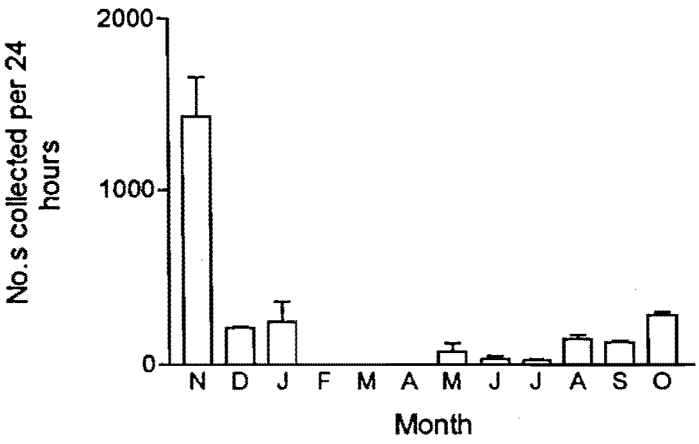
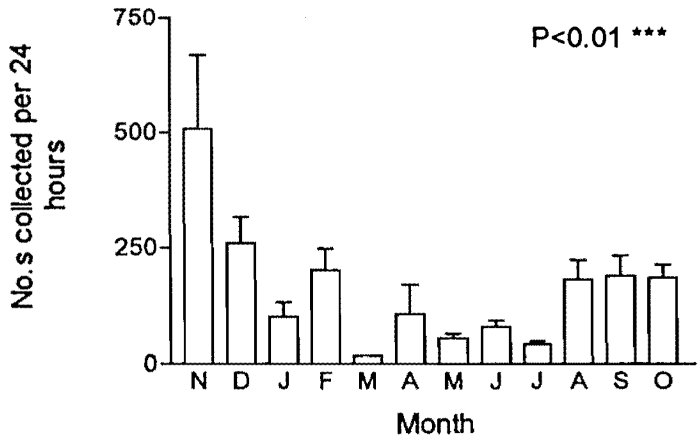


Fig. 4.5 Abundance of invertebrates in the drift (mean ± SE) during each month at Site 5.

a)



b)

	N	D	J	F	M	A	M	J	J	A	S	O
N		ns	ns	ns	***	**	**	ns	***	ns	ns	ns
D			ns	ns	***	**	**	ns	***	ns	ns	ns
J				ns	ns	ns	ns	ns	ns	ns	ns	ns
F					***	ns	ns	ns	*	ns	ns	ns
M						ns	ns	ns	ns	***	***	***
A							ns	ns	ns	ns	ns	*
M								ns	ns	ns	ns	*
J									ns	ns	ns	ns
J										*	*	**
A											ns	ns
S												ns

Fig. 4.6 a) Abundance of invertebrates in the drift (mean ± SE) each month using data from all sites.

b) Results of Dunn's Multiple Comparison test to determine where significance lies.

faunal abundance was 14 - 22 invertebrates per 24 hour sample (Fig. 4.7). In April, just prior to flow resumption at Site 5, the drift net collections at Site 4 were dominated by a large pulse of *Deleatidium* spp. (Fig. 4.7), despite the lack of current during the 24 hour sampling period. In May, following the return of flowing water to Site 5, few invertebrates were found in drift samples at Site 4. *H. aliena, Deleatidium* spp. and Chironomidae were most abundant, mean abundances of each being between 5 and 10 individuals per 24 hour sample (Fig. 4.7).

Although differences in drift abundance and density were recorded over the course of the year, it was difficult to relate these directly to differences in discharge (Fig. 4.8), since density of the benthos (the source of drifting individuals) also varied temporally. To overcome this, the proportion of the benthos in the drift was compared in relation to flow velocity. The proportion of the benthos drifting at all sites in November, February, June and September, ranged from 0.03 % to 1.57 %. Flow velocity and the proportion of the benthos in the drift were negatively correlated (r_s = -0.67; $P<0.01$) (Fig. 4.9), drift activity decreasing with increasing flow velocity.

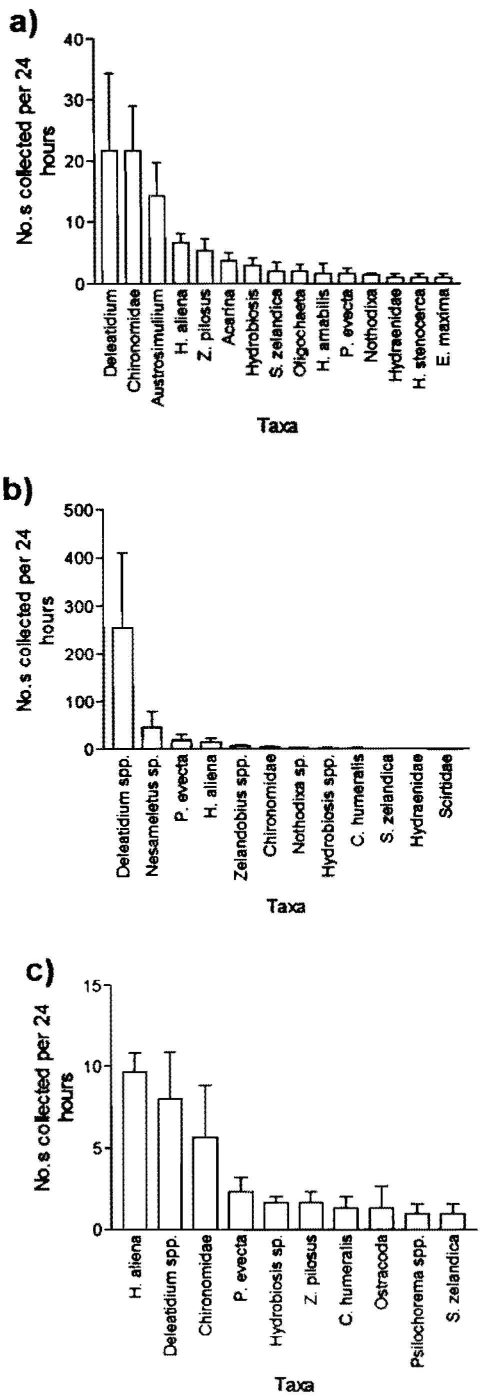


Fig. 4.7 Abundance of various taxa (mean ± SE) at Site 4 in a) December, b) April and c) May. Note that the scale of the y-axis varies.

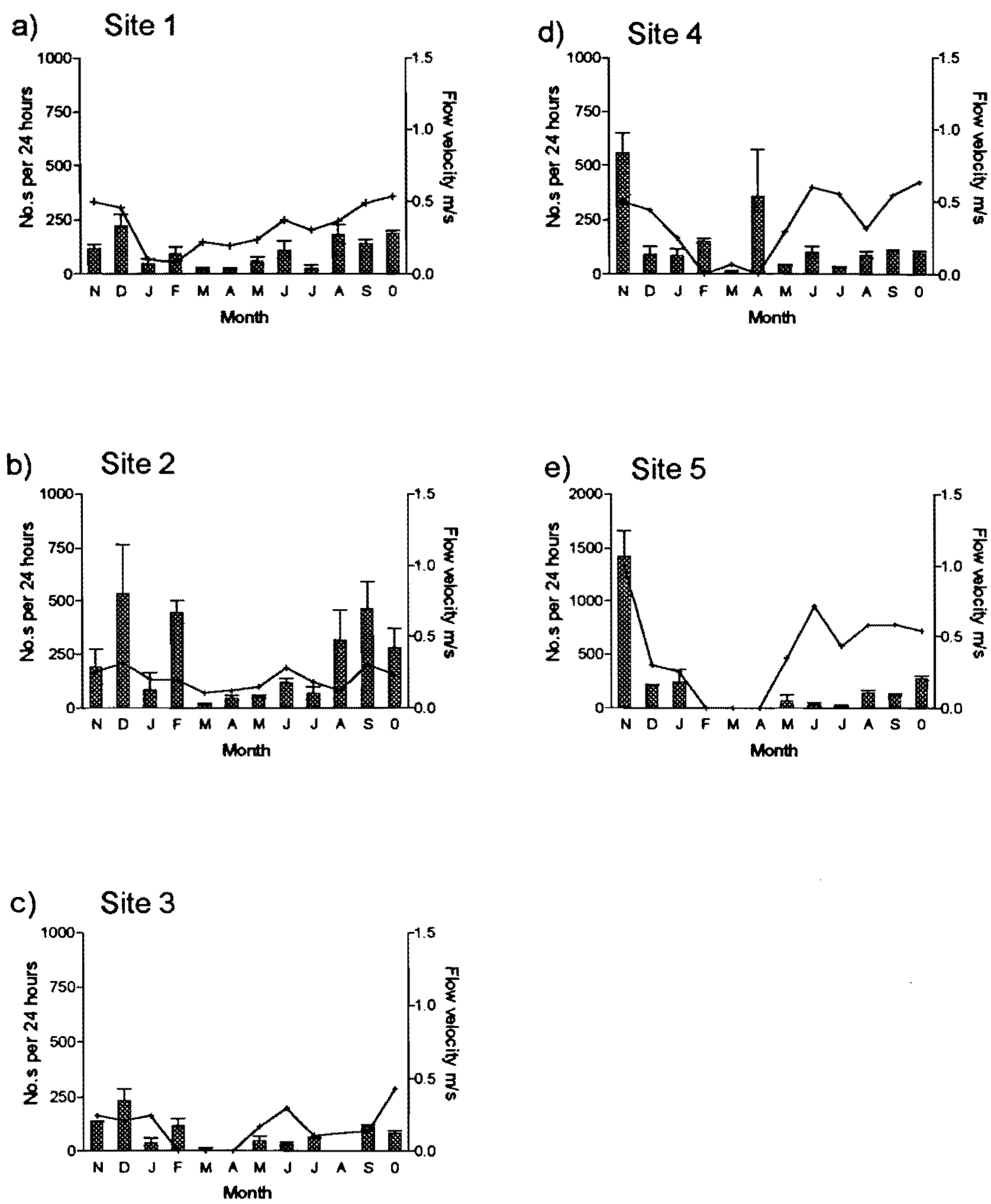


Fig. 4.8 Abundance of invertebrates (mean ± SE) (bars) and flow velocity (m/s) (line) each month at a) Site 1, b) Site 2, c) Site 3, d) Site 4 and e) Site 5. Note the scale differences.

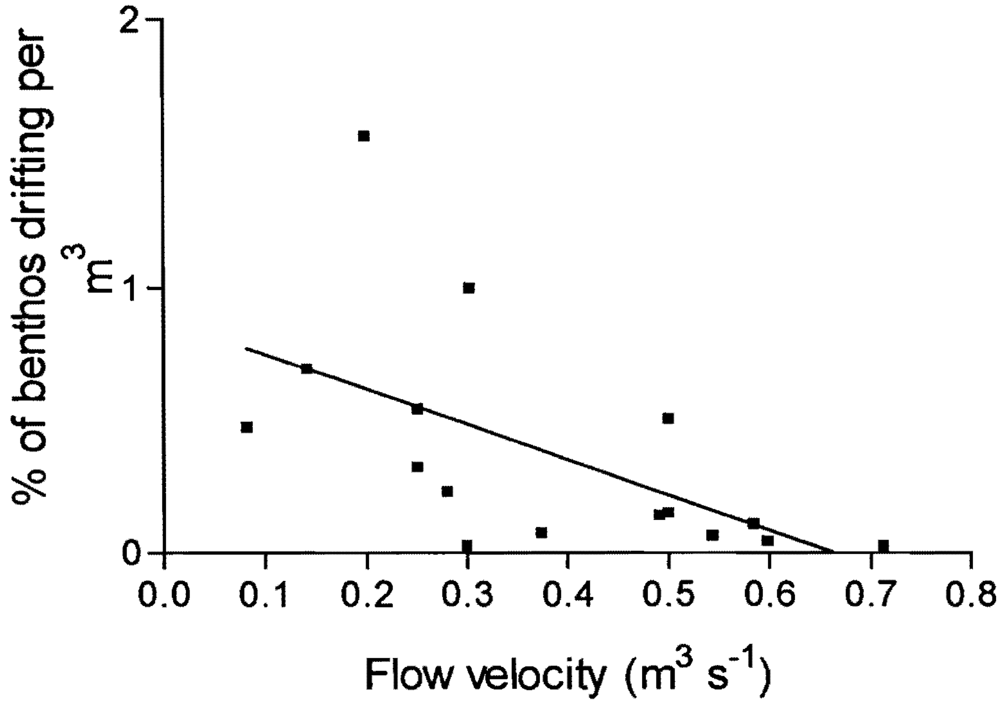


Fig. 4.9 The relationship between flow velocity (m^3s^{-1}) and proportion of benthos in the drift for all 5 sites in November, February, June and September, r_s=-0.67; P<0.01.

Discussion

A diverse and abundant assemblage of invertebrates occurred in the drift in Middle Bush Stream. Composition of the drift fauna did not differ markedly from the benthos, with 85 % of drifting taxa also occurring in benthic samples. This suggests that drift activity is a temporary event in the lives of most members of the benthic community, rather than being a phenomenon confined to a distinct subgroup of animals (Waters, 1972). Invertebrates that were found only in drift samples were taken in very low abundances, and their absence from benthic samples may have been through chance, or because they occur in microhabitats not encompassed by the benthic sampling program. *Zelandotipula* sp., for example, commonly inhabits seepages (Winterbourn & Gregson, 1989), and therefore was unlikely to have been collected in Surber samples.

Despite all sites having similar abundances of total drifting invertebrates and being dominated by *Deleatidium,* Chironomidae and *S. zelandica*, clear differences were found in the composition of the drifting faunas at the two upstream sites (Sites 1 & 2) and the three downstream sites (Sites 3, 4 & 5). *Zelandopsyche ingens* tended to be more abundant in the drift at Sites 1 and 2 than at the lower three sites, although the number of larvae (particularly those in early instars), caught in the drift at downstream sites increased following high flows in July. The similarity of the drift faunas at Sites 1 and 2, despite the location of Site 2 50 metres below the forest, indicates that some animals can drift considerable distances from the forest where their larval populations typically occur. For example, the occasional occurrence of *Z. ingens* (a species normally restricted to beech forest) at Site 5 (~650 m downstream from Site 1) demonstrates that extremely large distances can be travelled. Similarly, Winterbourn & Davis (1976) calculated that a substantial proportion (~25 %) of the population of *Z. ingens* was displaced downstream within Middle Bush forest by passive drift in an 8 month period. Brittain & Eikeland (1988) suggested that, in general, the distances travelled in an individual drift event vary from a few centimetres to several metres under "normal" flow conditions, however, under high flow conditions drift distances can increase greatly. O'Hop &

Wallace (1983) found a greater abundance of small insects in the drift during high flows, perhaps because they are less "skilled" at maintaining their position within the bed in such circumstances. Similarly, early instar larvae made up a large proportion of the increased numbers of *Z. ingens* drifting at all five sites following high flows in July. In general, the composition of the drift fauna at each site closely resembled that of the benthos. *Austrosimulium* sp. and *H. aliena* drifted in greater abundances at Sites 3, 4 and 5, probably due to their higher benthic densities there.

Seasonal comparisons of drift density and total drift abundance showed that maxima occurred in spring and summer and minima in winter. Similar seasonal trends have been observed in a range of temperate streams and rivers including some in New Zealand (McLay, 1968; Waters, 1969; O'Hop & Wallace, 1983; Brittain & Eikeland, 1988; Rincón & Lobón, 1997). Two local exceptions to this pattern have been documented. Graesser (1987) found no seasonal patterns in drift density over 16 months in three South Westland streams, and Watson (1971) found no variation in drift activity over four months in the Waitakere Stream near Auckland, despite an average 10°C drop in stream temperature during the period of his study. The seasonal changes in drift activity in Middle Bush Stream were not related to comparable changes in abundance of the benthos as found by McLay (1968) and Rincón & Lobón (1997). Benthic invertebrate abundances were significantly lower in summer (February) and higher in winter (June) in Middle Bush Stream (Fig. 3.2a), whereas drift abundances were significantly higher in summer (November and December) and lower in winter (April, May and July) (Fig. 4.6).

The finding of low drift abundances at all five sites approximately two weeks after flow resumed in May, indicates that while recolonisation of bare substrate from the drift did occur, it almost certainly happened gradually since drift abundances appeared to remain at low levels. In contrast, Paltridge *et al.* (1997) found that drift densities peaked 1 - 3 weeks after flow resumption in Magela Creek, a tropical, seasonally-flowing stream in Australia with perennial upper reaches. *H. aliena*, *Deleatidium* and Chironomidae were the dominant taxa found drifting into Site 5 two weeks after flow resumption, and their larvae were also found in Surber samples there at the same time. This indicated that recolonisation of the denuded substrate had been occurring during the previous two weeks, although only at low densities. Thus, while it is clear that drift played an important role in the recolonisation of the intermittent zone, the extent of its contribution is likely to be dependent on factors such as season (affecting abundance and composition of the upstream fauna) and flow velocity.

During February, March and April, substantial numbers of invertebrates were caught in drift samplers in standing water at Sites 3 and 4. Some invertebrates, such as the mayfly *Baetis* sp. (Waters, 1969), have been observed to alter their behaviour and increase drift activity at very low water velocities (Lancaster *et al.*, 1996). However, in Middle Bush Stream invertebrates appeared to be actively moving into the traps, rather than drifting, since no current was present. High water temperature (up to 29°C at Site 4), and, because of this (i.e. the high temperature) and a lack of water mixing, reduced oxygen concentrations in stream water (Brittain & Eikeland, 1988; Ward, 1992), may have resulted in a general increase in the activity of physiologically stressed individuals. This certainly appeared to be the case at Sites 4 and 5 in January, when larvae of many species were visible during the day moving over the substrate in all directions, swimming and "drifting" on minor currents in essentially still water. According to Brittain & Eikeland (1988) some mayflies move into flowing water or increase their swimming behaviour in order to meet respiratory requirements. Similarly, chironomid larvae may undulate their bodies to create currents to supply 'new' water to respiratory epithelia, thereby reducing the depth of the diffusion barrier (Ward, 1992). In March when flow velocity at Site 4 rose perceptibly but was still extremely low (Fig. 4.8d), drift net catches were also very low suggesting physiological stress was no longer a significant issue. At this time water temperature had declined to approximately 14°C and a diverse benthic fauna was still present (Chapter 3).

The negative relationship between drift activity and flow velocity found in Middle Bush Stream indicates that a larger proportion of the benthos drifts at low water velocities. A similar relationship was found in three highly disturbed South Westland streams by Graesser (1987), who hypothesized that invertebrates may actively avoid entering the water column under periods of increased discharge. Such behaviour could partially explain the relatively low drift densities observed at Sites 4 and 5 following the resumption of flow. In contrast, positive relationships between the abundance (or density) of drifting invertebrates and current velocity have been reported in several studies (Watson, 1971; Waters, 1972; Townsend & Hildrew, 1976; Dance & Hynes, 1979; Bird & Hynes, 1981), although some authors noted that such relationships were restricted to specific seasons (autumn-early winter: Bird & Hynes, 1981), environments (permanent streams: Dance & Hynes, 1979) or taxa (for example, Chironomidae: Brittain & Eikeland, 1988, but not *Baetis* sp.: Bird & Hynes, 1981; Brittain & Eikeland, 1988). Of particular interest in relation to my study was the finding of a strong positive correlation between weekly discharge and drift abundance in a permanent stream, but not in a nearby intermittent stream (Dance & Hynes, 1979). In fact, like me, they found increases in drift activity with decreasing flow velocity in the intermittent stream. Although two studies represents a very small sample it is tempting to suggest that fundamental differences in drift behaviour may occur between at least some characteristic inhabitants of temporary and permanent streams.

CHAPTER FIVE

THE HYPORHEOS

Introduction

The term 'hyporheic zone' refers to the interstitial habitat within a streambed, bounded by the surface water of the stream above, and by true ground water below (Fraser *et al.*, 1996). Characteristically, this zone is spatially limited to, at most, a few metres beyond the stream channel (Stanford & Ward, 1988), however, the extent varies from stream to stream in response to a suite of environmental factors. These include grain size, porosity of the bed sediments, physical extent of alluvial sediment and physicochemical conditions (Ward, 1992; Scarsbrook 1995; Scarsbrook & Halliday, 1996). Streams flowing over bedrock or unstable sandy beds often lack a well developed hyporheic community, due to the absence of interstitial spaces (Gray & Fisher, 1981; Boulton & Suter, 1986). The hyporheic fauna, referred to as the 'hyporheos', is commonly divided into two groups: the occasional hyporheos, which includes invertebrates that only inhabit the hyporheic zone for part of their lifecycle (and are therefore potential colonists of the benthos); and the permanent hyporheos, those invertebrates that complete their entire lifecycle in the hyporheic zone (Williams & Hynes, 1974).

Studies of permanently flowing streams carried out in North America (Coleman & Hynes, 1970; Williams & Hynes, 1974; Godbout & Hynes, 1982; Pugsley & Hynes, 1986; Palmer *et al.*, 1992; Fraser *et al.*, 1996), Europe (Efford, 1960; Hynes *et al.*, 1976; Morris & Brooker, 1979), Malaysia (Bishop, 1973), Australia (Marchant, 1988; 1995), and New Zealand (Scarsbrook, 1995; Huryn, 1996; Adkins, 1997), have demonstrated that the hyporheic zone of streams and rivers often contains a diverse and abundant invertebrate assemblage. The potential role of the hyporheos as a source of "surface" colonists in temporary streams was suggested by Williams (1977), who found that migration from the hyporheic zone was important in a North American temporary stream. More recently, several studies have considered the role of the hyporheic zone as a refuge for invertebrates in intermittently flowing streams (North America: Boulton *et al.*, 1992a; Boulton & Stanley, 1995; Clinton *et al.*, 1996; Africa: Gagneur & Chaoui-Boudghane, 1991; Australia: Cooling & Boulton, 1993; Paltridge *et al.*, 1997). They showed that the response of the hyporheos to channel drying varied between locations, and was strongly influenced by the ability of the substrate to retain interstitial water after surface water had disappeared. The hyporheos was eliminated shortly after channel drying in streams with hyporheic zones that rapidly lost interstitial water, making it unimportant as a refuge for stream fauna (Gagneur & Chaoui-Boudghane, 1991; Boulton & Stanley, 1995; Paltridge *et al.*, 1997). In contrast, hyporheic invertebrates survived dry periods in streams that retained interstitial water after surface flow ceased (Boulton *et al.*, 1992b; Cooling & Boulton, 1993; Clinton *et al.*, 1996). Boulton *et al.*, (1992b), referred to the subset of the hyporheos that survived when surface water disappeared, as the 'dry channel hyporheic assemblage'. Studies in several North American desert streams (Boulton *et al.*, 1992b; Clinton *et al.*, 1996) and a South Australian arid-zone stream (Cooling & Boulton, 1993) indicated that this assemblage is characterised by water mites, ostracods, copepods, chironomid larvae, ceratopogonid larvae, isopods and nematodes.

In this chapter I report the results of an investigation of the hyporheic fauna of Middle Bush Stream during constant flow and during drying of the streambed. My research focussed on the following questions:

1) Do elements of the fauna occur in hyporheic refuges when surface water is absent?
2) Does the hyporheos provide a source of stream channel colonists
    a) when water returns to the stream?
    b) during continuous flow?
3) Does the importance of the hyporheic zone as a refuge vary seasonally?

Methods

Hyporheic samples were taken from two sites, Site 3 where the channel remained wet for the entire sampling period, and Site 5 where the channel was dry from late January until late April 1997. Nine colonisation tubes were installed at each site, three sampling the top 0-10 cm of streambed, three sampling depths of 10-20 cm, and three sampling depths of 20-30 cm. The three types of samplers allowed potential movements of invertebrates up and down in the substrate to be assessed.

Each hyporheic sampler consisted of a section of PVC pipe (105 mm diameter, 400 mm length) with holes drilled at one of three depths (approximately 80 holes, 10 mm diameter) (Plate 5.1). A plastic cap prevented aerial colonisation of the samples by insects and a tightly fitting plastic disk at the bottom of each pipe prevented invertebrate colonisation from beneath. Clean substrate collected from beside the channel at the two sites was placed inside the samplers in flexible nylon mesh bags (~10 mm mesh), which allowed the substrate to come into close contact with the sides of the pipe. The bags of substrate were removed each month and invertebrates that had colonised them were washed from the stones, concentrated in a net (0.5 mm mesh), and preserved in 95 % methylated spirits. Invertebrates were sorted in a Bogorov tray under 60X magnification and were identified as described in Chapter 3.

Abundances of Diptera and Oligochaeta were compared between sites using the non-parametric Mann-Whitney U-test. Kruskal-Wallis tests were used to compare dipteran abundance at three depths, and dipteran and total invertebrate abundance between months.

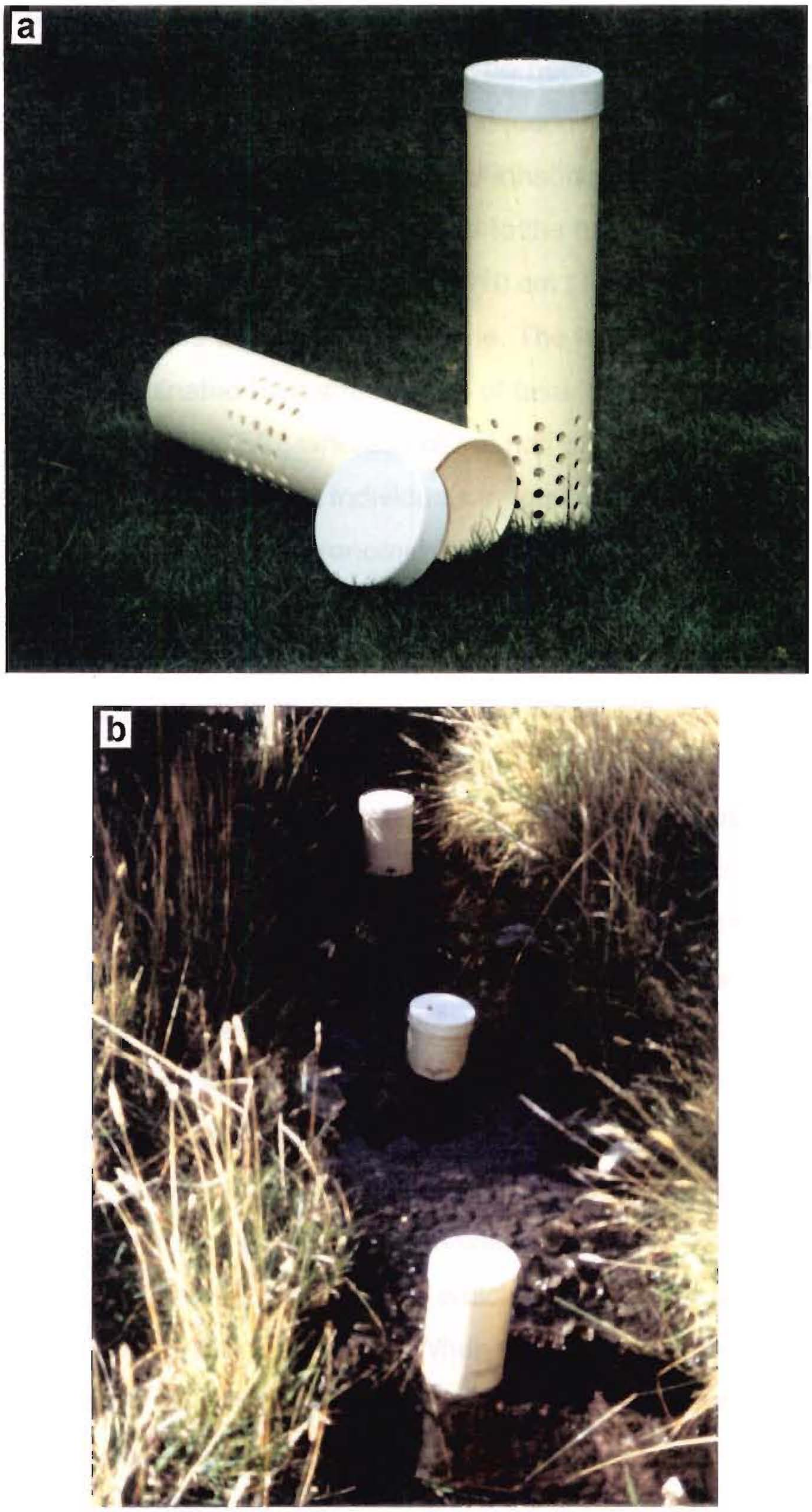


Plate 5.1 a) Example of hyporheic samplers and lids, with holes at two depths. Pipes are 400 mm long and 105 mm in diameter.

b) Hyporheic samplers in Middle Bush Stream at Site 3.

Results

Fifty-one taxa were collected from the hyporheos over the 12 month period. All were considered to be members of the 'occasional hyporheos' (Williams & Hynes, 1974), as they were also found inhabiting surface sediments (Chapter 3), and thus were not restricted to the hyporheic habitat. Thirty-nine taxa occurred at depths exceeding 10 cm (Table 5.1), and 35 taxa were taken from the 20-30 cm depth zone. The hyporheic fauna was numerically dominated by a small group of taxa, most notably the Chironomidae (Table 5.2), whereas about half of the taxa (26) were represented by less than ten individuals in total (Table 5.1).

About 50 % of the chironomid fauna occurred within the top 10 cm of the bed, however, the remaining 50 % were spread evenly between the 10-20 cm and 20-30 cm depth strata (Table 5.2). Their common occurrence down to 30 cm suggests that Chironomidae would also have occurred at even greater depths. The considerably smaller population of Oligochaeta (mainly lumbricid earthworms) had a similar vertical distribution, with a large proportion of individuals occurring deeper than 10 cm. In contrast, *Spaniocerca zelandica* and *Deleatidium* populations were concentrated in the top 10 cm of streambed, while *Potamopyrgus antipodarum* and *Hudsonema aliena* were more evenly spread, with similar proportions in the 0-10 cm, 10-20 cm and 20-30 cm zones. *Darwinula* sp. (Ostracoda) was most commonly found in the 20-30 cm zone.

In December, when Middle Bush Stream was flowing throughout its length, the hyporheos at Sites 3 and 5 was very similar. At both sites the dominant taxon present was Diptera, which consisted almost exclusively of Chironomidae (98.7%) (Fig. 5.1a). When flow ceased at Site 5 in late January (Fig. 5.1b), the top 30 cm of the streambed dried within hours, and interstitial water was never observed in the pipes when the channel was dry. Numbers of chironomids in pipes at Site 5 fell immediately, whereas large populations were maintained at Site 3. Numbers of Oligochaeta at Site 5 increased slightly and significantly compared with Site 3 in January ($P<0.01$), and numbers of Trichoptera, Ephemeroptera and Plecoptera also fell.

Table 5.1 Abundances of taxa (total numbers collected during the study period) and depth distribution within hyporheic samplers at Sites 3 and 5.

		Depths (cm)		
Taxa	**n**	**0-10**	**10-20**	**20-30**
Trichoptera				
Beraeoptera roria	1			+
Helicopsyche sp.	1	+		
Hudsonema aliena	190	+	+	+
Hudsonema amabilis	9	+	+	+
Oeconesus maori	38	+	+	+
Olinga spp.	37	+	+	+
Oxyethria albiceps	7	+		+
Philorheithrus agilis	28	+	+	+
Pycnocentria evecta	71	+	+	+
Pycnocentria funerea	1	+		
Zelandopsyche ingens	2	+	+	
Edpercivalia maxima	44	+	+	+
Hydrobiosella stenocerca	5	+		
Hydrobiosis spp.	24	+	+	+
Hydrobiosis parumbripennis	3	+		
Hydrobiosis spatulata	1	+		
Hydrochorema crassicaudatum	1	+		
Hydrochorema tenuicaudatum	3	+		+
Plectrocnemia sp.	4	+		
Polyplectropus sp.	116	+	+	+
Psilochorema spp.	86	+	+	+
Plecoptera				
Austroperla cyrene	1			+
Cristaperla fimbria	35	+	+	+
Spaniocerca zelandica	429	+	+	+
Stenoperla prasina	5		+	+
Zelandobius spp.	16	+	+	
Zelandobius pilosus	96	+		+
Ephemeroptera				
Austroclima jollyae	1	+		
Coloburiscus humeralis	5	+		+
Deleatidium spp.	293	+	+	+
Nesameletus sp.	2	+		
Diptera				
Austrosimuliium sp.	10	+	+	+
Ceratopogonidae	7	+	+	
Chironomidae	8481	+	+	+
Eriopterini sp. 1	1	+		
Eriopterini sp. 2	1	+		
Hexatomini	9	+	+	+
Muscidae	42	+	+	+
Nothodixa sp.	39	+	+	+
Paradixa sp.	3		+	
Oligochaeta	739	+	+	+

Table 5.1 (continued)

Coleoptera				
Elmidae	4		+	+
Hydraenidae	52	+	+	+
Hydrophilidae	3	+		
Scirtidae	9	+		+
Mollusca				
Potamopyrgus antipodarum	231	+	+	+
Crustacea				
Darwinula sp.	179	+	+	+
Acarina	13	+	+	+
Nematomorpha				
Gordiidae	7	+		+
Platyhelminthes				
Neppia montana	12	+		+
Mecoptera				
Nannochorista philpotti	28	+	+	+

Table 5.2 Total numbers of the most abundant taxa (n>150 over 12 month period) at Sites 3 and 5, and the proportions (%) found at each depth.

		Depths (cm)		
Abundant taxa	**n**	**0-10**	**10-20**	**20-30**
Chironomidae	8481	53.4	20.7	25.9
Oligochaeta	739	40.5	34.2	25.3
Spaniocerca zelandica	429	76.2	12.1	11.7
Deleatidium spp.	293	75.8	15.0	9.2
Potamopyrgus antipodarum	231	39.4	29.4	31.2
Hudsonema aliena	190	43.2	20.0	36.8
Darwinula sp.	179	34.6	19.6	45.8

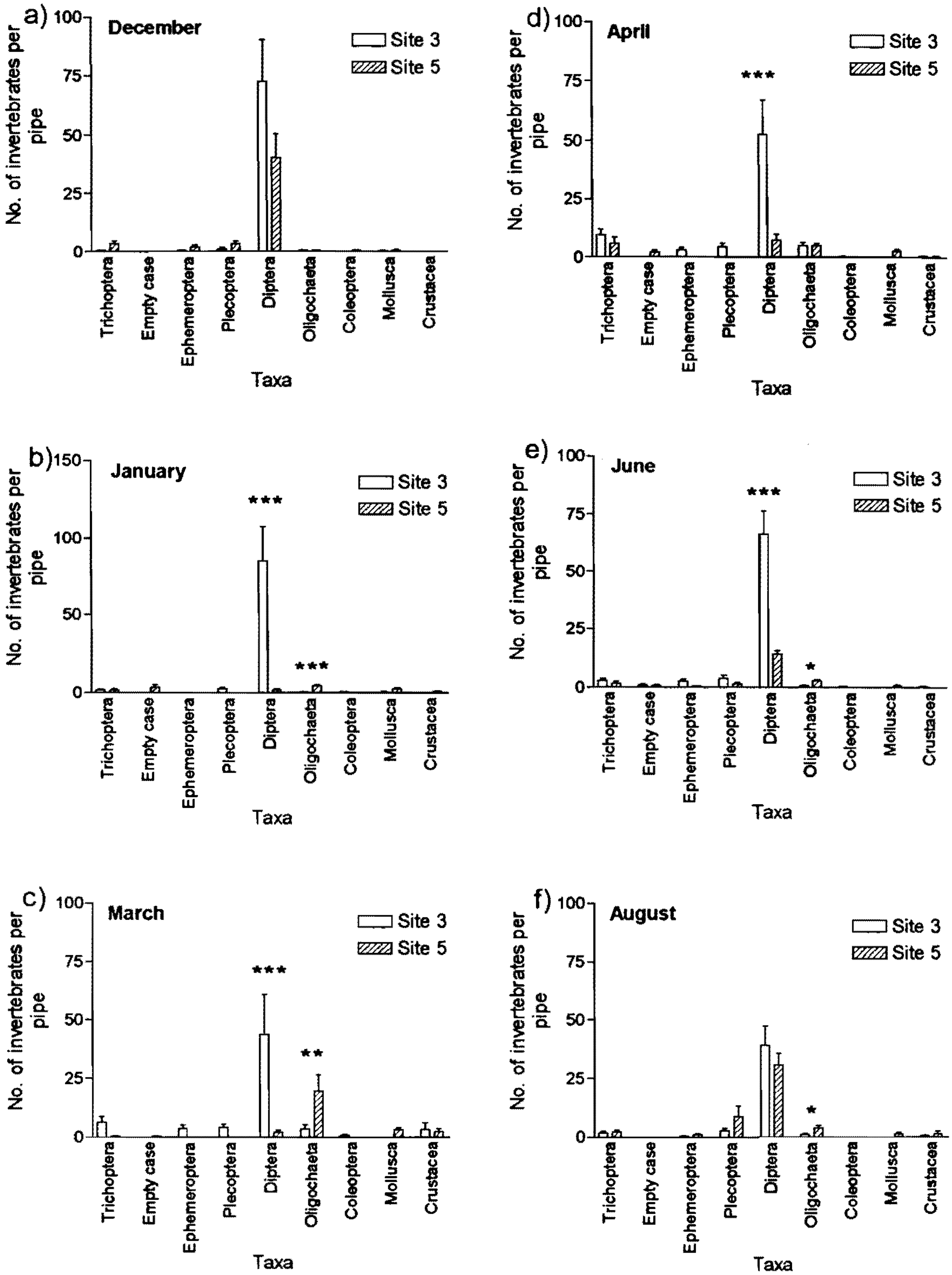


Fig. 5.1 Numbers (mean ± SE) of various taxa in hyporheic samples at Site 3 (constantly flowing) and Site 5 (dry from late January - late April) in a) December, b) January (note different scale), c) March, d) April, e) June and f) August. Significant differences in abundances of Diptera and Oligochaeta at Site 3 and Site 5 are shown (Mann- Whitney U-test, $P<0.05$).

As the dry period at Site 5 extended into March, dipteran abundance remained low and the number of oligochaetes present increased (Fig. 5.1c). In contrast, the streambed remained wet at Site 3 and Diptera (mainly Chironomidae) continued to dominate the hyporheos. Small larval caddisfly, mayfly and stonefly populations also persisted at Site 3.

When flow resumed at Site 5 in April (Fig. 5.1d) the number of oligochaetes in pipes fell immediately. The number of Diptera increased slightly, but remained significantly lower than at Site 3 ($P<0.01$). Numbers of caddisfly larvae (mainly *Hudsonema aliena*, *Pycnocentria evecta* and *Psilochorema* spp.) rapidly increased to pre-drying levels, but numbers of mayflies and stoneflies remained extremely low. The hyporheic dipteran fauna at Site 5 gradually increased in the five months following flow resumption (Figs. 5.1e, 5.1f), and attained similar abundance to that found at Site 3 in August (Fig. 5.1f). The gradual recolonisation of the hyporheos at Site 5 by Diptera, contrasts with the high abundances maintained at all times at Site 3, and is illustrated in Fig. 5.2.

In November, Sites 3 and 5 both had large dipteran faunas at all three depths (Fig 5.3a), although Site 3 had significantly greater abundance overall (Fig 5.2). However, when drying began at Site 5 in late January, the dipteran fauna rapidly disappeared from all three depths (Fig. 5.3b), and remained essentially absent in March after prolonged drying of the streambed (Fig. 5.3c). When rewetting occurred in late April, chironomids reinvaded all three depth classes of the hyporheos at similar rates ($P=0.254$) (Fig. 5.3d). Population numbers remained very similar in May, June, July and August (Fig. 5.3e-h) at all three depths.

Total invertebrate abundance at Site 3 (all depths combined) did not differ significantly between months ($P=0.41$), or within each of the three depth classes considered separately (0-10 cm, $P=0.06$; 10-20 cm, $P=0.71$; 20-30 cm, $P=0.84$) (Fig. 5.4). The Diptera showed the same pattern, except that at a depth of 0-10 cm abundances differed significantly among months ($P=0.02$). This general lack of seasonal variation contrasts with that found in the benthos, and was particularly surprising at the 0-10 cm depth where I had expected to find changes in abundance mirroring changes detected in

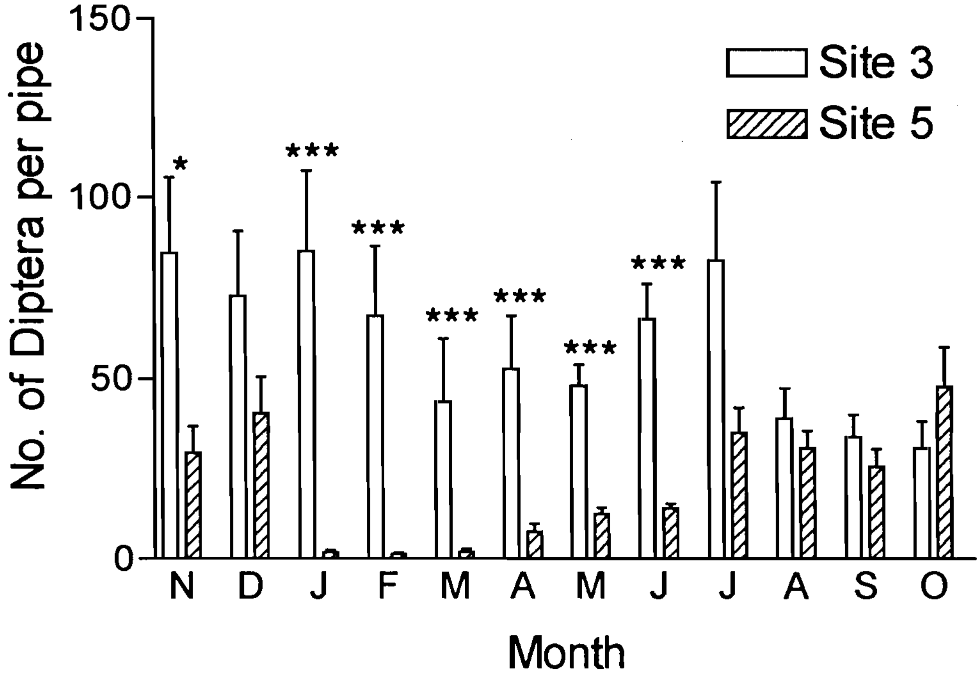


Fig. 5.2 Number of Diptera per pipe (mean ± SE) at Site 3 (constantly flowing) and Site 5 (dry from late January-late April) each month. Significant differences in abundance between sites are shown (Mann-Whitney U-test, * = P< 0.05; *** = P< 0.001).

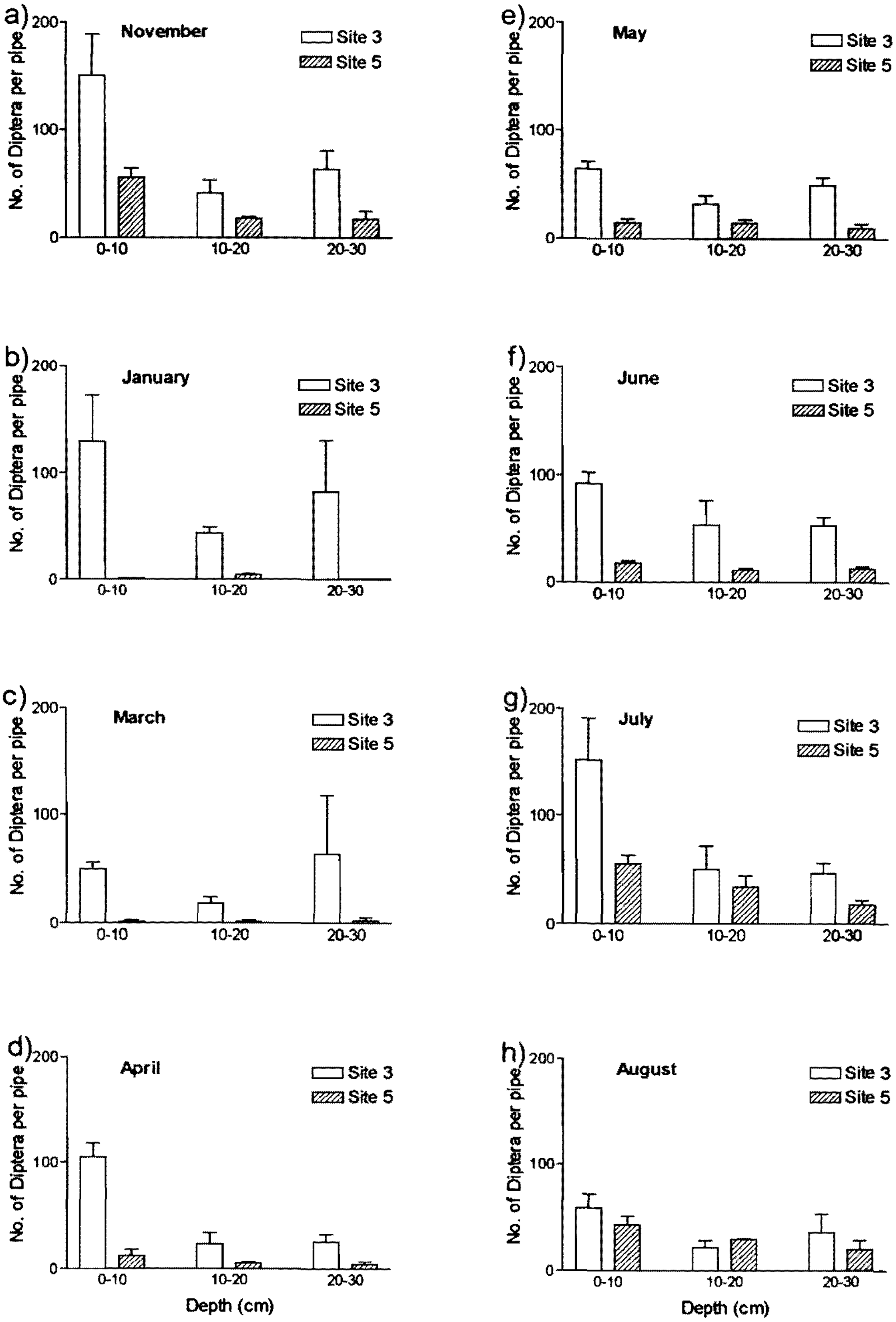


Fig 5.3 Number of Diptera per pipe (mean ± SE) at 3 depths at Site 3 (constantly flowing) and Site 5 (dry from late January-late April), in a) November, b) January, c) March, d) April, e) May, f) June, g) July and h) August.

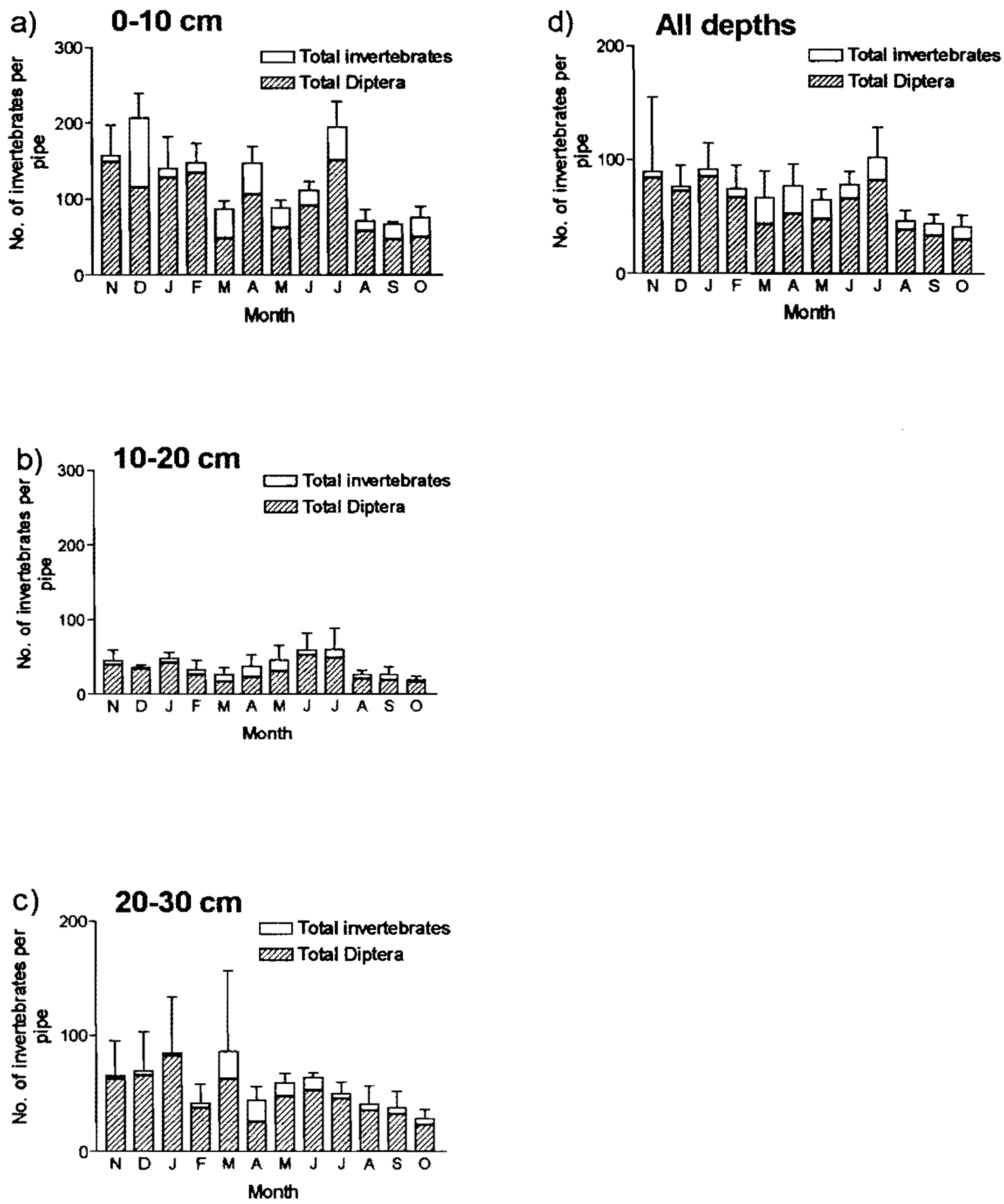


Fig. 5.4 Total invertebrate abundance and dipteran abundance (mean ± SE) in Site 3 hyporheic samples at a) 0-10 cm, b)10-20 cm, c) 20-30 cm and d) at all depths combined over the 12 month sampling period.

the benthic samples (Chapter 3). This contradictory result is likely to have been an artefact of the different sampling techniques used: Surber samples measure what is present in the top 10 cm of streambed directly, whereas the colonisation tubes rely on animal movements.

Discussion

When Middle Bush Stream was flowing in its lowermost section, Chironomidae dominated the hyporheic community to a depth of at least 30 cm. Smaller numbers of individuals belonging to a diverse array of taxa also inhabited the hyporheic zone at depths exceeding 10 cm, including 14 Trichoptera, 6 Plecoptera, 2 Ephemeroptera, 7 Diptera, 3 Coleoptera, Oligochaeta, Mollusca, Ostracoda, Acarina, Nematomorpha, Platyhelminthes and Mecoptera. Chironomid larvae are often abundant or dominant members of the hyporheos (Coleman & Hynes, 1970; Williams & Hynes, 1974; Morris & Brooker, 1979; Godbout & Hynes, 1982; Marchant, 1988, 1995; Boulton & Stanley, 1995), their ability to survive in such high abundances in interstitial environments possibly being due to their body shape (slender, flexible bodies) (Williams & Hynes, 1974; Williams, 1984), or their ability to tolerate variable physicochemical conditions, such as decreasing concentrations of dissolved oxygen (Williams, 1984). Other taxa that were commonly found at depths exceeding 10 cm in Middle Bush Stream, may also be morphologically pre-adapted to an interstitial existence by having long, slender, flexible bodies (Oligochaeta, *Hudsonema aliena*), small, blunt bodies with a hard shell (*Potamopyrgus antipodarum*), or extremely small size (*Darwinula* sp.) (Williams & Hynes, 1974; Williams, 1984).

While most individuals and taxa occurred in the top 10 cm of streambed, high proportions of the relatively abundant chironomid, oligochaete, *P. antipodarum*, *H. aliena* and ostracod populations occurred at depths exceeding 10 cm. In contrast, a high proportion of the dominant mayfly and stonefly populations (*Deleatidium* spp. and *Spaniocerca zelandica*) were restricted to the top 10 cm of the bed (~76%). Williams & Hynes (1974) also found that maximum abundance of invertebrates occurred in the top 10 cm of streambed, as did Ford (1962), Morris & Brooker (1979), Marchant (1988, 1995), Scarsbrook (1995) and Adkins (1997). Some taxa, such as Ephemeroptera (Morris & Brooker, 1979; Marchant, 1988, 1995; Scarsbrook 1995; Adkins, 1997), Plecoptera (Marchant, 1988, 1995), Trichoptera (Morris & Brooker, 1979; Marchant, 1995; *Oxyethira albiceps*: Scarsbrook, 1995), and Simuliidae (Morris & Brooker, 1979), tend to be concentrated in this top layer. In contrast, other taxa may be more widely distributed within the top 30 cm or more of streambed; for example, some Chironomidae (Williams & Hynes, 1974; Morris & Brooker, 1979; Godbout & Hynes, 1982; Marchant, 1995; Adkins, 1997), Oligochaeta (Morris & Brooker, 1979) and Elmidae (Marchant, 1995). An exception to this distributional trend was documented by Ford (1962), who found that 98% of chironomids were restricted to the top 5 cm of stream bed in a muddy bottomed stream. Compaction of the fine, muddy sediment probably eliminated interstitial pore spaces and caused reduced oxygen levels, thus making the hyporheic zone uninhabitable for chironomid larvae.

Drying of the stream bed at Site 5, and the subsequently rapid drying of the hyporheic zone, caused a dramatic change in the composition of the hyporheos in a relatively short time (several weeks at most). Abundances of chironomid larvae and other strictly aquatic fauna declined immediately at all three depths and I found no evidence of migration by aquatic invertebrates into deeper substrate (at least down to 30 cm). As the streambed became increasingly dry and adventitious weeds began to grow in the stream channel, the oligochaete population within the bed increased and aquatic fauna virtually disappeared. Similarly, the hyporheos did not provide a refuge for benthic invertebrates during the drying up of a Sonoran desert stream (Boulton & Stanley, 1995), or a West-Algerian stream (Gagneur & Chaoui-Boudghane, 1991), since interstitial water was lost rapidly and the substrate became baked and compact. Clinton *et al.* (1996) found that as surface water disappeared from a desert stream, the crustacean-dominated hyporheos moved deeper into the substrate (to depths of at least 1 metre), as the water table fell. The hyporheic zone did not provide a refuge for chironomid and ceratopogonid larvae, however, as they did not move deeper into the sediments as the water table fell.

Lastly, several studies of desert streams have described a 'dry channel hyporheic biotope' (consisting of an assemblage of water mites, Crustacea, dipteran larvae and nematodes), which exists temporarily after surface water disappears (Boulton *et al.*, 1992b; Cooling & Boulton, 1993). No equivalent assemblage was observed in Middle Bush Stream, however, where the vertical disappearance of water within the hyporheic zone was rapid. Furthermore, rewetting of Site 5 in late April resulted in a rapid decline in oligochaete abundance, suggesting that many of the worms that invaded the dry stream bed were terrestrial species. Chironornids gradually reinvaded the hyporheic zone during the following four months, but showed no preference for a particular depth zone. The very gradual rate of reinvasion of my sampling tubes suggests that chironomids were recolonising the hyporheic zone primarily from sources other than deeper in the hyporheic zone.

The lack of seasonal variation in abundance of the hyporheos at Site 3, where surface water was present year round, contrasted with the findings of Williams & Hynes (1974), Godbout & Hynes (1982), Pugsley & Hynes (1986), Marchant (1995) and Adkins (1997), who all documented seasonal trends. While dipteran abundance varied seasonally in the top 0-10 cm of the bed, no such trend occurred in the 10-20 cm and 20-30 cm depth zones. In contrast, Adkins (1997) observed reduced densities of chironomids during winter in the hyporheos of the forested section of Middle Bush Stream, where it is likely that a different pool of chironomid species dominated the fauna.

In summary, my findings indicate that the hyporheos was unimportant as a source of colonists when flow resumed in lower Middle Bush Stream in late April. The rapid rate of drying of the stream (i.e., loss of interstitial water), and the prolonged nature of the dry period, resulted in the development of an essentially terrestrial community within the dry streambed, rather than a water-saturated hyporheic zone that could be used as a refuge by aquatic invertebrates. When the stream was constantly flowing, the hyporheic zone supported a diverse community dominated numerically by chironomids, the seasonal abundance of which did not vary markedly. Thus, the hyporheic community was simply a vertical extension of the stream surface community, whose members disperse vertically as well as laterally within the streambed.

CHAPTER SIX

FLIGHT AND OVIPOSITION

Introduction

Many aquatic insect species have highly mobile, winged, adult stages, which commonly disperse from their natal habitats and colonise new bodies of water. The members of some insect orders are more mobile than others: caddisflies are stronger fliers than mayflies or stoneflies, for example (Sheldon, 1984). Aerial colonisation of a new aquatic habitat may occur in two ways. Coleoptera and Hemiptera usually colonise directly, with long-lived, winged adult stages flying to a new body of water where they often persist, with or without reproducing, for several months (Sheldon, 1984). In contrast, members of orders such as Ephemeroptera, Plecoptera, Trichoptera and Diptera colonise indirectly, by depositing eggs in the stream channel. The eggs may be attached to stones or be loose within the streambed, and they may be deposited singly or in a mass, sometimes in a gelatinous matrix (Anderson & Wallace, 1984).

Flight by adult insects is a particularly important colonisation pathway in desert streams recovering after severe flood events (Gray & Fisher, 1981; Meffe & Minckley, 1987). Exceptionally short generation times, continuous reproduction throughout the year, rarity of diapause, and the presence of aerial adults at most times, often allow extremely rapid recolonisation of these highly disturbed streams (Meffe & Minckley, 1987). In intermittently flowing streams, the contribution of flying insects to recolonisation of the benthos varies widely in importance. Oviposition by aerial adults that had emerged from a nearby permanent stream, was an important pathway in the recolonisation of an intermittent Rhodesian stream (Harrison, 1966). Flight and oviposition were also considered primarily responsible for the re-establishment of caddisfly populations in four streams in central Scotland following a drought (Morrison, 1990), and for insect colonisation of a temporary stream in Iraq (Carl, 1989). In contrast, other studies of streams with intermittent flow have found flight to be unimportant as a colonisation vector, with different pathways (such as invertebrate drift or vertical migration from the hyporheos) dominating recolonisation (e.g., Williams, 1977; McArthur & Barnes, 1985; Paltridge *et al.*, 1997).

The importance of flight in the recolonisation of temporary streams, is influenced by several variables. Proximity of the intermittent stream to more permanent waters may influence the abundance and diversity of colonists available (Cushing & Gaines, 1989). Seasonal timing of the dry phase and the time of flow resumption influences what potential colonists will be available (Cushing & Gaines, 1989; Mackay, 1992; Ward, 1992), since periods of flight activity vary between insect species. In New Zealand, many (but not all) stream insects have poorly synchronised life histories (Winterbourn, 1978), and they often display extended flight and egg-hatching periods (Winterbourn *et al.*, 1981). While this makes propagules of some species available for colonisation in most months of the year, the timing of flow resumption in intermittent streams dictates whether other taxa with short flight periods are available as colonists.

In this chapter I report the results of an investigation of the flight activity of mayflies, stoneflies and caddisflies along the lower half of Middle Bush Stream, carried out using sticky traps. I set out to address two questions:

1) Do terrestrial adult lifestages of aquatic insects provide a source of colonists:
    a) when water returns to the stream?
    b) during continuous flow?
2) Does the importance of flight and oviposition by adult insects as a colonisation pathway vary seasonally?

Methods

Flight

Winged adult stages of mayflies, stoneflies and caddisflies were collected from each site on a monthly basis during the 12 month study period, using sticky traps. Each trap consisted of a sheet of clear plastic (450 mm x 1200 mm), which was folded in half and suspended from a rope attached to two iron posts, one on each side of the channel. The plastic sheet was coated on one side with Tanglefoot® (a clear, odourless, sticky, waterproof substance) using a paint brush, and was then hung over the rope so that the trap was sticky on both sides. Plastic clothes-pegs were used to secure the plastic sheet to the rope.

One sticky trap was used at each site and the insect-coated plastic sheets were removed and replaced with clean ones each month. After the plastic sheets were removed they were cut into small pieces and placed inside plastic containers containing mineral turpentine for 1-2 days. This dissolved the Tanglefoot®, releasing the insects from the plastic sheeting without damaging them. The insects were then rinsed with water and 95 % methylated spirits before being preserved in 95 % methylated spirits. Mayflies, stoneflies and caddisflies were later sorted and counted in a Bogorov tray at 10-60X magnification. They were identified to species level by Prof. M.J. Winterbourn, using keys and descriptions published by Neboiss (1986) and with reference to the work of Shearer (1995). Confirmation of the identities of most caddisfly adults was made by Dr. J. Ward (Canterbury Museum). Other insects with aquatic larvae that were captured, such as Diptera and Coleoptera, were not considered in this study.

Oviposition

Egg-laying activity of caddisflies was assessed by placing 12 large rocks in the channel at each site. The top of each rock protruded from the water to allow ovipositing adults to land on the rock and then crawl underneath to deposit their eggs. Egg masses attached to the rocks were counted each month, and circled with a wax pencil to prevent them from being counted again the following month. Egg masses could not be associated with particular species but most belonged to the Hydrobiosidae (and Philorheithridae, Site 1).

Results

A total of 19 649 adult Trichoptera, Plecoptera and Ephemeroptera, all with aquatic larval stages, were captured during the 12 month study period. The Trichoptera was the most diverse and numerous order, containing 33 taxa and 95.8 % of the individuals caught (Table 6.1). Three mayfly and four stonefly taxa were also taken (Table 6.1).

Composition of species assemblages varied between sites, with distinct differences between collections made at the upstream (Sites 1 & 2) and downstream sites (Sites 3, 4 & 5). This spatial variation is illustrated in Fig. 6.1, which shows the relative similarity of the faunas at the five sites, as indicated by presence / absence data. Sites 1 and 2 were dominated by the hydrobiosid caddis *Edpercivalia maxima*, which was less common at Site 3 and seldom taken at Sites 4 and 5 (Table 6.2). In contrast, *Oxyethira albiceps* was the dominant species at the three downstream sites, but was uncommon at Site 2 and only one individual was found at the forested Site 1 (Table 6.2). *Pycnocentria evecta*, *Psilochorema tautoru* and *Hydrobiosis parumbripennis* were also more commonly collected at the downstream sites, whereas *Zelandopsyche ingens*, *Hydrochorema tenuicaudatum* and *Hydrobiosella stenocerca* were concentrated in or near the forest at Sites 1 and 2 (Table 6.2).

Numbers of adult insects collected varied seasonally, being highest during summer and lowest during winter (Fig. 6.2). All the commonly collected insects exhibited reduced abundances in June and July (Fig. 6.3). Flight periods differed among species, with individuals of some species (*H. stenocerca*, *H. parumbripennis* and *O. albiceps*) being found all year round. In contrast, *Z. ingens* and *P. evecta* had short flight periods and were found only from November to March and November to April, respectively (Fig. 6.3).

Many of the benthic species found at Site 5, including *Deleatidium*, *S. zelandica*, *E. maxima* and *P. tautoru*, had adults with long flight periods (Fig. 6.3), allowing colonisation of the benthos by oviposition to occur in most months. In contrast, the short flight periods of *P. evecta* (November-April; Fig. 6.3), *Hudsonema aliena* (December-April) and *Olinga* spp. (November-

Table 6.1 List of taxa collected on sticky traps samples at each site (+ = more than one individual present, * = one individual present), over the 12 month sampling period.

	Site				
	1	2	3	4	5
Trichoptera					
Aoteapsyche colonica			+	+	+
Aoteapsyche tipua	+				
Beraeoptera roria			+	+	+
Costachorema psaroptera		+	+		
Costachorema xanthoptera	*			+	+
Edpercivalia fusca	*	+	+		
Edpercivalia maxima	+	+	+	+	
Hudsonema aliena	*	+	+	+	
Hudsonema amabilis	+	+	+		*
Hydrobiosella mixta	+				
Hydrobiosella stenocerca	+	+	+	+	+
Hydrobiosis clavigera			*		
Hydrobiosis harpidiosa			+		
Hydrobiosis parumbripennis	+	+	+	+	+
Hydrobiosis silvicola				+	
Hydrobiosis soror				*	
Hydrobiosis spatulata	+	+		+	
Hydrochorema crassicaudatum	+	+	+		*
Hydrochorema tenuicaudatum	+	+		*	
Neurochorema confusum			+	+	+
Oeconesus maori	+	+	+	+	+
Olinga feredayi		*	+	+	+
Olinga jeanae	+	+	*		
Oxyethira albiceps	*	+	+	+	+
Philorheithrus agilis	+	*	+		
Polyplectropus altera				+	+
Psilochorema bidens			+	+	+
Psilochorema leptoharpax		+	+		
Psilochorema tautoru	+	+	+	+	+
Pycnocentria evecta			+	+	+
Pycnocentrodes aureola			*	*	+
Synchorema tillyardi	*				
Zelandopsyche ingens	+	+			
Plecoptera					
Cristaperla fimbria	+	*	*	*	
Spaniocerca zelandica	+	+	+	+	+
Zelandobius confusus	*	+	+		
Zelandobius furcillatus -gp*	+	+	+	+	+
Ephemeroptera					
Coloburiscus humeralis			+	+	+
Deleatidium spp.	+	+	+	+	+
Nesameletus sp.	*	+	+	+	+

* includes *Z. pilosus*

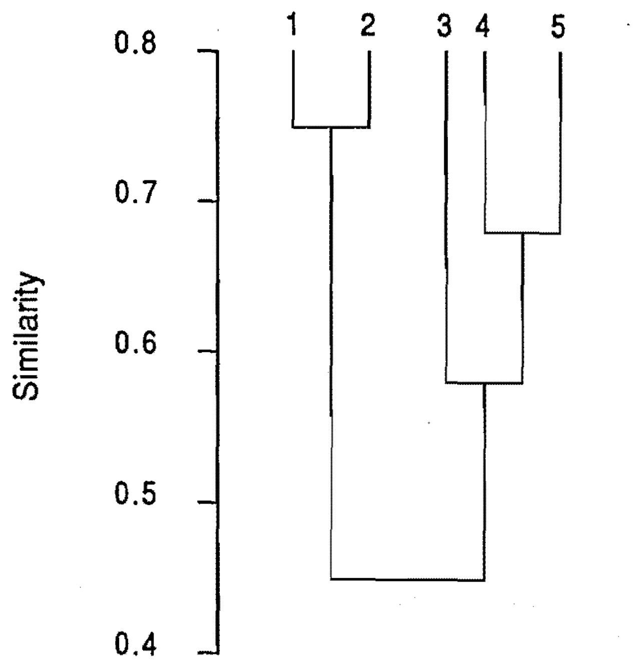


Fig. 6.1 Cluster analysis of Sites 1-5 using presence/ absence data obtained from sticky trap collections.

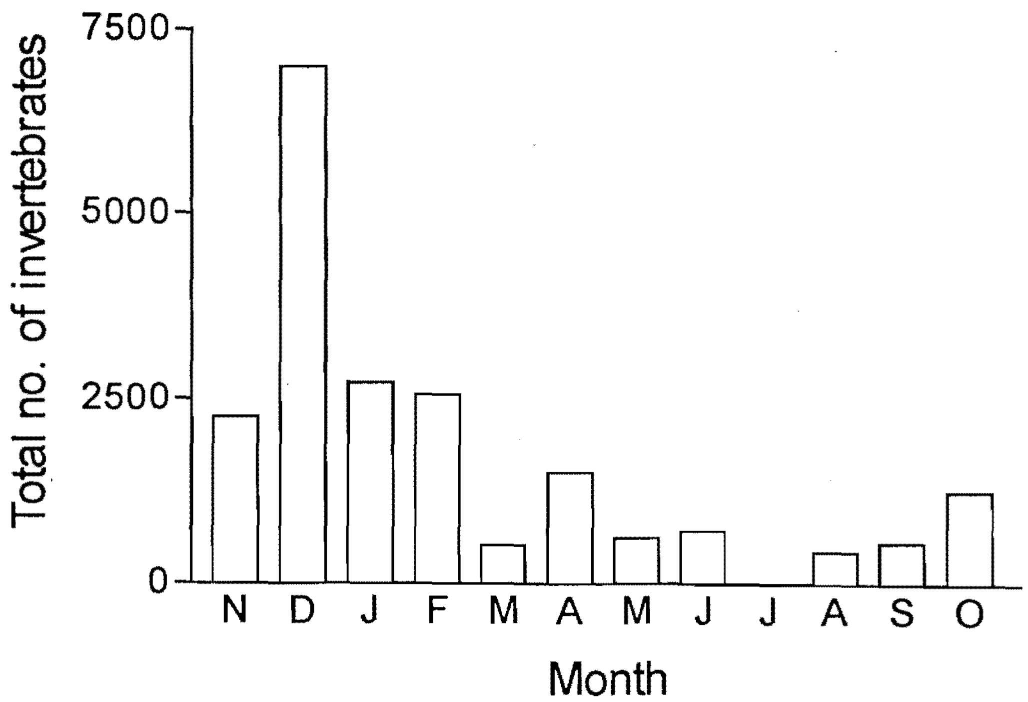


Fig. 6.2 Total number of adult Trichoptera, Plecoptera and Ephemeroptera collected each month, data from all five sites combined.

Table 6.2 The five most abundant taxa in order of abundance at each site, all sampling dates combined.

	Order of abundance				
	1	2	3	4	5
Site 1	*Edpercivalia maxima*	*Hydrochorema tenuicaudatum*	*Hydrobiosella stenocerca*	*Zelandopsyche ingens*	*Spaniocerca zelandica*
Site 2	*Edpercivalia maxima*	*Zelandopsyche ingens*	*Hydrobiosis parumbripennis*	*Deleatidium* spp.	*Oxyethira albiceps*
Site 3	*Oxyethira albiceps*	*Hydrobiosis parumbripennis*	*Edpercivalia maxima*	*Deleatidium* spp.	*Psilochorema tautoru*
Site 4	*Oxyethira albiceps*	*Pycnocentria evecta*	*Hydrobiosis parumbripennis*	*Psilochorema tautoru*	*Deleatidium* spp.
Site 5	*Oxyethira albiceps*	*Pycnocentria evecta*	*Hydrobiosis parumbripennis*	*Psilochorema tautoru*	*Zelandobius furcillatus* -gp

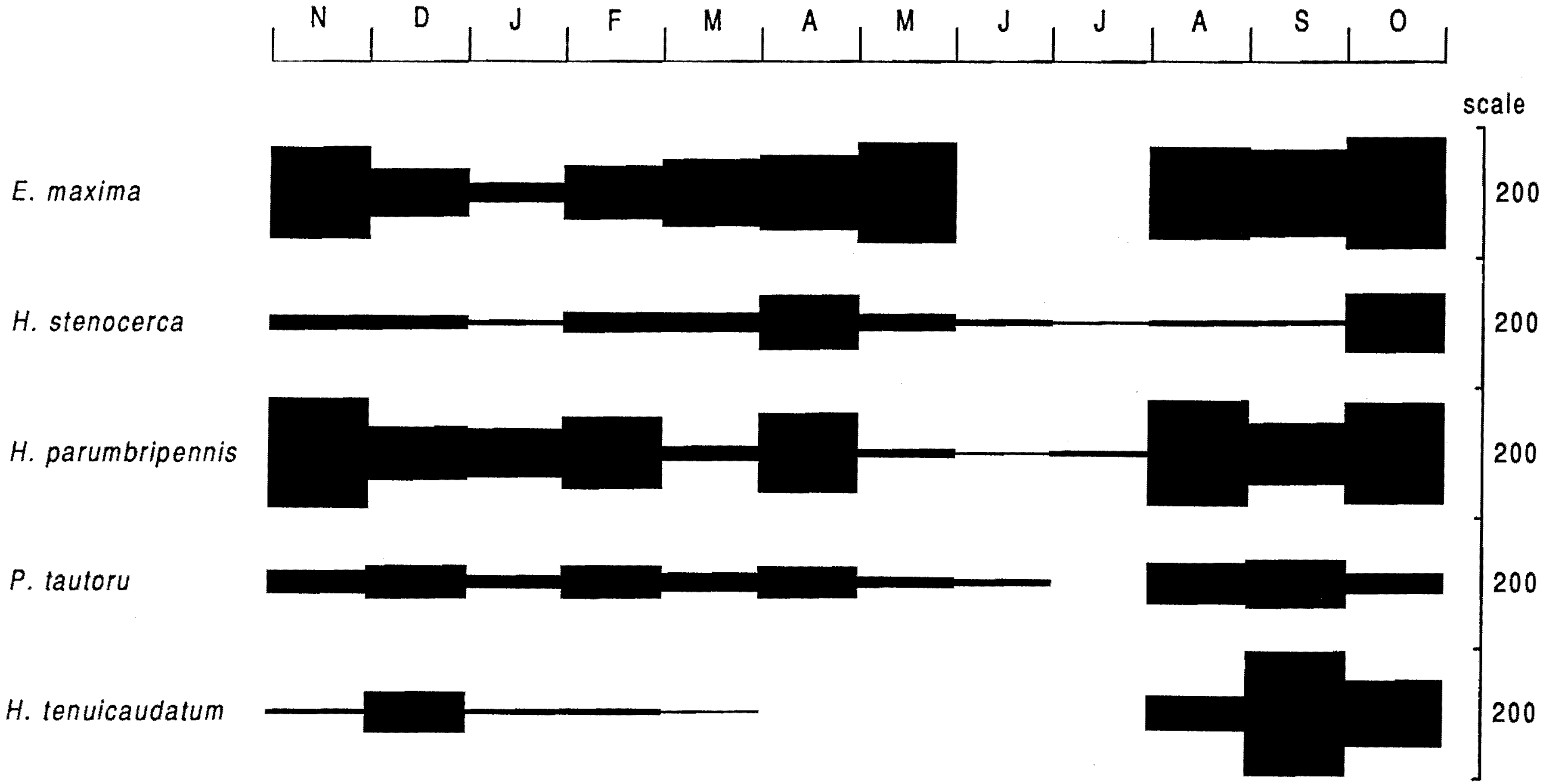


Fig. 6.3 Seasonal abundances of the 10 most common taxa collected in the study (all sites combined).

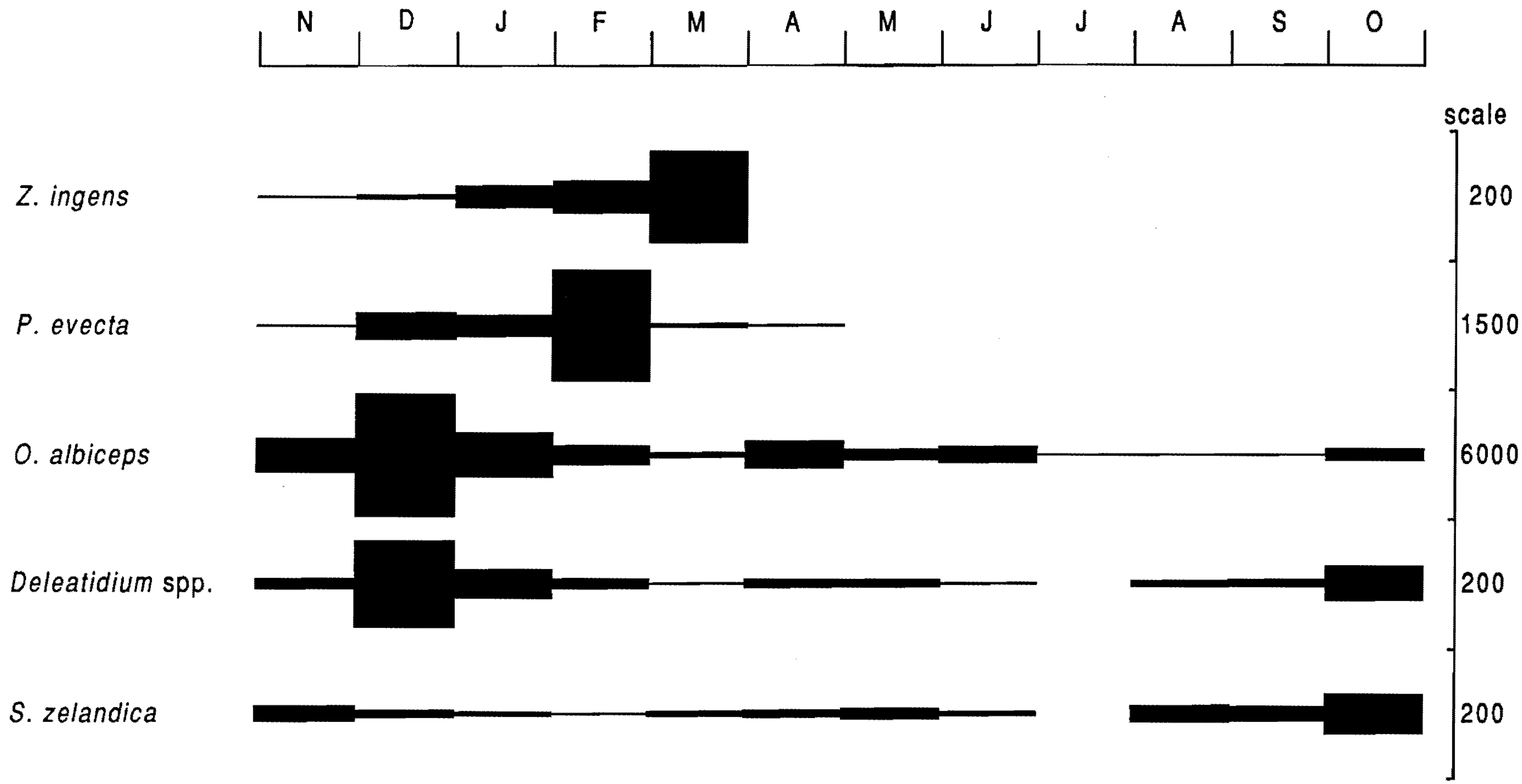


Fig. 6.3 (continued) Seasonal abundances of the 10 most common taxa collected in the study (all sites combined). Note that the scale varies.

February) restrict benthic colonisation by oviposition to a few months during summer and autumn.

Collections made at Sites 4 and 5 during and following flow resumption, provide the best indication of which insect species were available to recolonise Site 5 **directly** via oviposition. The number of caddisflies, stoneflies and mayflies on the sticky traps at Sites 4 and 5 were relatively low in April when rewetting occurred, and also in May and June following flow resumption (Fig. 6.4). *O. albiceps* dominated the collections, although *H. parumbripennis* was also relatively common and nine other species, including *Deleatidium*, *P. tautoru* and *E. maxima*, also occurred at these times (Table 6.3).

Trichopteran egg masses were deposited on stones at at least one site during all but one (July) month of the year (Table 6.4), confirming that oviposition by adults was a regular means of colonisation. Oviposition activity had a comparable periodicity to flight activity, being highest in summer and autumn and lowest during winter (Fig 6.5). A total of 46 egg masses (all probably Hydrobiosidae) were found at Sites 4 and 5 in April and May following the resumption of flow, confirming that at least some recolonisation of Site 5 was by oviposition. In contrast to Sites 4 & 5, most of the attached egg masses found at Site 1 in the forest belonged to *Philorheithrus agilis*, not species of Hydrobiosidae. The large numbers of egg masses observed in December and January reflects the short flight period of this species (Appendix 4).

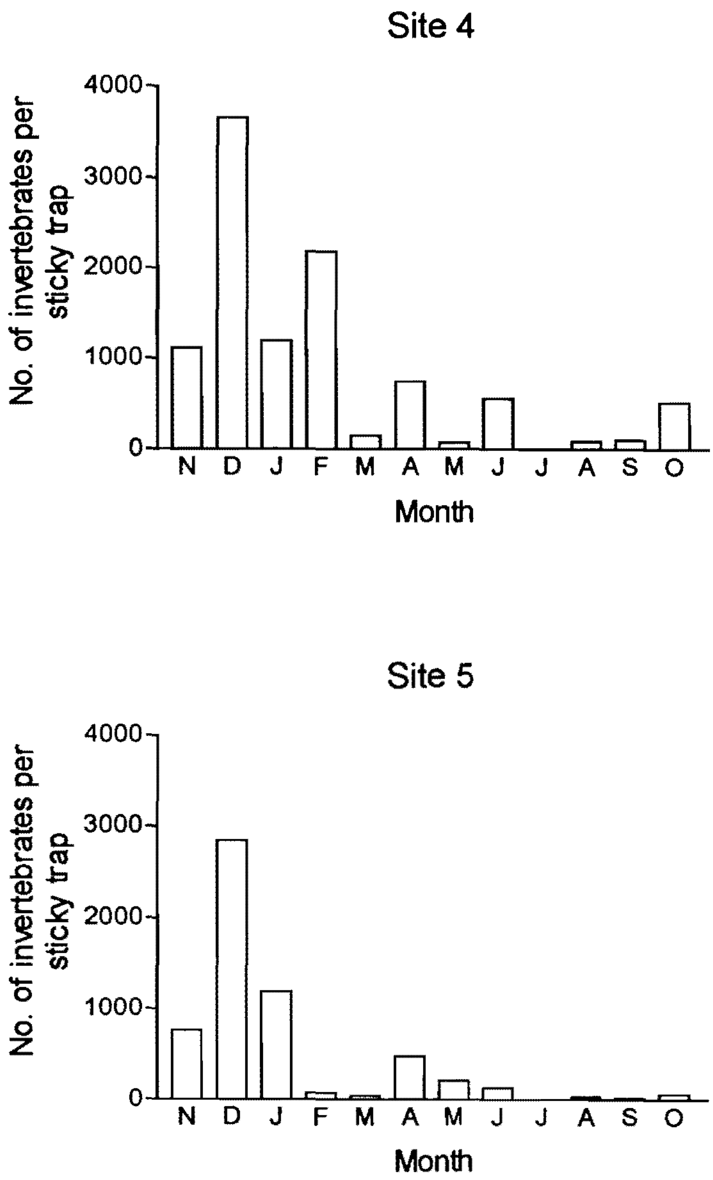


Fig. 6.4 Total number of adult Trichoptera, Plecoptera and Ephemeroptera collected each month on sticky traps at Sites 4 and 5. Note that the y-axis scales differ.

Table 6.3 Total numbers of the seven most abundant insect taxa caught on sticky traps during April and May at all five sites and at Sites 4 and 5.

Insect taxa	Total numbers	Numbers at Sites 4 & 5
E. maxima	266	3
H. stenocerca	100	1
H. parumbripennis	132	112
P. tautoru	55	41
O. albiceps	1495	681
Deleatidium spp.	23	11
S. zelandica	26	1

Table 6.4 Numbers of egg masses recorded on 'oviposition stones' at each site from November 1996 to September 1997.

Site	N	D	J	F	M	A	M	J	J	A	S
1	0	52	17	5	6	0	0	0	0	0	2
2	1	1	1	3	0	1	0	0	0	0	0
3	7	5	1	3	2	5	7	0	0	1	2
4	4	4	5	36	12	27	3	0	2	1	1
5	8	5	1	0	0	9	7	0	2	5	3

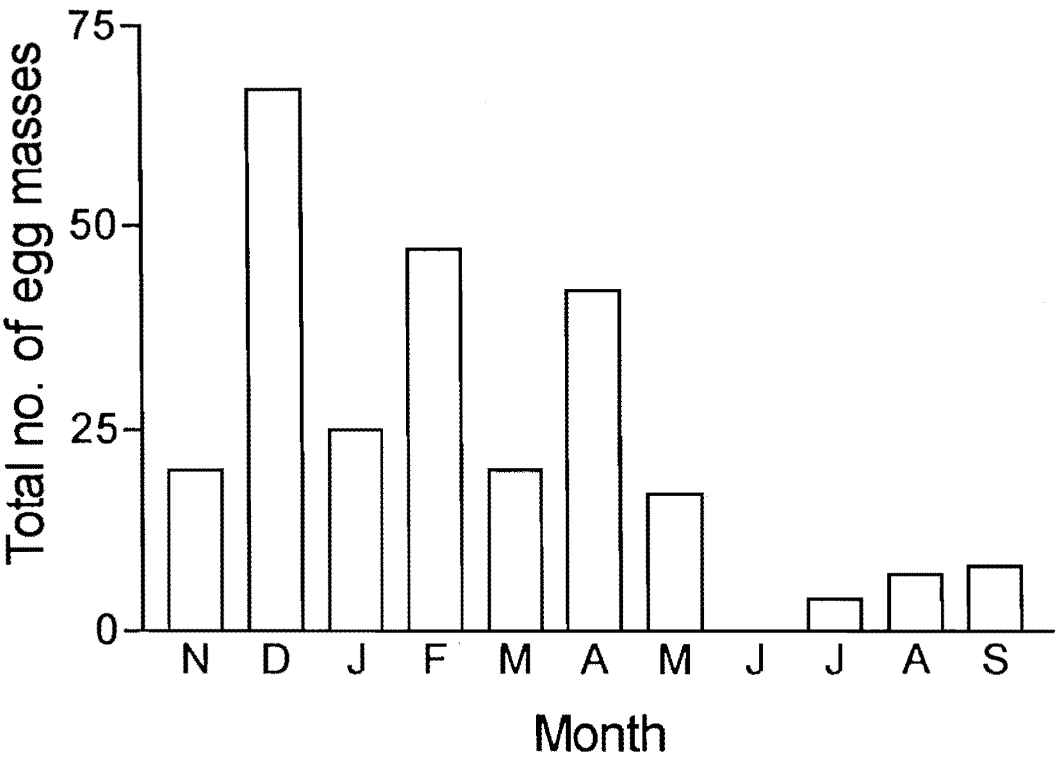


Fig. 6.5 Total number of egg masses collected each month, from all five sites.

Discussion

Of the three orders of aquatic insects collected as adults alongside Middle Bush Stream, Trichoptera was the most diverse and abundant. This reflected the wide diversity of larval Trichoptera inhabiting lotic waters in the region, including both Middle Bush Stream and Grasmere Stream (Chapter 3; Death, 1991), and the fact that caddisflies are strong fliers (Sheldon, 1984). Shearer (1995) also documented a diverse and abundant caddisfly fauna in the vicinity of Middle Bush Stream, using both sticky traps and light traps.

Ephemeroptera and Plecoptera were less diverse and abundant on sticky traps than Trichoptera, but some representatives were found in most months and they occurred at all five sites. Most abundant were *Deleatidium*, *S. zelandica* and two species of *Zelandobius*. Large numbers of Diptera (including representatives with both aquatic and terrestrial larvae) were also present on traps, particularly during summer. While insects within this order were not formally identified or counted, large numbers of adult Chironomidae were often present. Many of them had probably emerged from Middle Bush Stream or were returning to the stream to oviposit.

Composition of the adult insect fauna differed between forest and grassland sites, in a similar manner to the benthic and drifting invertebrates (Chapters 3 & 4). The forest appeared to act as a barrier to many adult caddisfly species, with different insect assemblages being collected at the sites associated with the forest (Sites 1 & 2) and the sites below it, in tussock grassland (Sites 3, 4 & 5). Adult caddisflies collected only at sites within or near the forest were *E. maxima*, *Z. ingens*, *H. tenuicaudatum* and *H. stenocerca*. Larvae of three of these species (*E. maxima*, *Z. ingens* and *H. stenocerca*) were found in the benthos at forested Site 1, and all were absent or rare as larvae at the grassland sites (Chapter 3). Thus it seems that these species complete their lifecycles in close proximity to the forest.

In contrast, adult *O. albiceps*, *P. evecta*, *P. tautoru* and *H. parumbripennis* were concentrated at the three grassland sites, and all of these were also collected in light and sticky traps beside Grasmere Stream by Shearer (1995). Larvae of all four species were collected from Middle

Bush Stream at Sites 3, 4 and 5 (Chapter 3), and also Grasmere Stream (Death, 1991), but they were absent or rare at Sites 1 and 2 of Middle Bush Stream (Chapter 3). The predominance of *O. albiceps* adults at the grassland sites, did not mirror a similar abundance of the species in the benthos of either Middle Bush Stream or Grasmere Stream, where benthic populations were relatively small. This suggests that their larvae may occur principally in swamps, seeps and backwater regions of streams, all of which are abundant in the close vicinity of Cass. Hydroptilids may also be able to fly relatively long distances across open grassland, but my results suggest they rarely enter patches of forest. The low abundance of larvae in the benthos of Middle Bush Stream throughout the study period also indicates that *O. albiceps* was not successfully colonising Middle Bush Stream, despite the abundance of adults, many of which laid eggs on the sticky traps! The reasons for this are difficult to assess, and I was unable to determine whether the very small eggs were deposited in the streambed.

As in this study, an investigation of trichopteran assemblages in temporary headwater streams in Oregon, documented differences in faunal composition between streams flowing through forest and grassy meadows (Anderson & Dieterich, 1992). Four trichopteran species were collected almost exclusively from a meadow stream (both in the benthos and emergence traps), whereas six species occurred only in forest streams. Differences in shading between the two habitat types, and consequent differences in food availability, temperature and exposure to predators, were suggested as reasons for the observed variation in caddisfly populations (Anderson & Dieterich, 1992).

Some adults were flying above Middle Bush Stream throughout the sampling period, however, abundances were very low in June and July, and several species were absent (e.g., *E. maxima*, *Z. ingens*, *P. evecta*, and *H. tenuicaudatum*). Adult *Deleatidium* and *S. zelandica* had long flight periods, and were only absent in July. Oviposition activity by caddisflies was also minimal during winter, as indicated by my counts on stones. Numbers of potential aerial colonists, and oviposition activity, were highest during summer (from November to February), when several species with short flight periods occurred (*P. evecta*, *Z. ingens*), and insects that were present as adults for most of the year occurred in peak abundances (e.g., *O. albiceps*, *Deleatidium*). Similarly, numbers of adult insects (particularly Ephemeroptera and Trichoptera), peaked in an Australian tropical stream in mid-summer, and abundances were low in winter (Benson & Pearson, 1987). Changes in temperature are considered to be a major factor responsible for seasonal differences in flight and oviposition activity (Sweeney, 1984; Mackay, 1992).

When flow resumed at Site 5 in April, flight activity had begun to decline. While many species that had inhabited the benthos at Site 5 before the channel dried (such as *Deleatidium*, *S. zelandica*, *E. maxima* and *P. tautoru*), were still present as adults, many occurred in low abundances (such as *Deleatidium* which peaked in abundance in December), and others were not collected at Site 5 (such as *E. maxima* which was concentrated in or near the forest). The short flight period of *P. evecta* precluded it from directly colonising the stream at Site 5 in the months following flow resumption. This points to the importance of timing of flow periodicity in relation of colonisation through oviposition.

The timing of flow resumption dictates the importance of this pathway and what species can utilise it in any particular year. If rewetting had occurred two months earlier, the greater abundance and diversity of adult insects would have enhanced the probable importance of this pathway in the initial recolonisation of Site 5. However, if rewetting had been postponed until June, aerial adults would have been greatly reduced in numbers, diminishing the importance of colonisation in this manner.

In summary, flight and oviposition by mayflies, stoneflies and caddisflies, did not appear to be a particularly important recolonisation pathway following flow resumption at Site 5. However, hydrobiosid caddisflies (species of *Hydrobiosis* and *Psilochorema* at least) did lay their eggs in the lower reaches of Middle Bush Stream, and both adults and egg masses were common at Site 5 in April and May. Thereafter, presence of adults of most species declined as autumn and winter progressed, and their opportunity to contribute to the population of the intermittent reach was limited in the six months following resumption of flow. Nevertheless, egg masses were present at Site 5 in all months except June when water was present, indicating that at least low levels of recruitment via oviposition are likely to be on-going in the intermittent reach.

CHAPTER SEVEN

CONCLUDING DISCUSSION

The aim of my study was to investigate colonisation pathways operating in Middle Bush Stream, in relation to a changing flow regime and seasonality. To achieve this, benthic, drift, hyporheic and non-aquatic adult invertebrate faunas were sampled over a 12 month period. During the study period, the stream channel in the lower grassland reach dried up for three months, from late January to late April, and recolonisation of this reach was assessed following flow resumption. Although research focussing on recolonisation of intermittent streams has received increased attention in the last decade (Chapter 1), this study is the first to consider the process in a New Zealand stream.

At the perennially flowing forested and grassland sites, invertebrate drift, aerial migration and vertical migration from the hyporheos all contributed to colonisation of the benthos (Fig. 7.1). Taxonomic assemblages using the three pathways and the two riparian biotopes differed to varying degrees, with the activity of potential colonists being greatest during summer, particularly via the aerial and drift pathways. While the same three taxa (*S. zelandica*, Chironomidae, and *Deleatidium*) dominated the drift fauna at the forested and grassland sites, this pathway also supported the most diverse assemblage of potential colonists, and its overall taxonomic composition showed a distinct difference between forested and grassland sites. Caddisflies (and possibly Diptera which were not considered in this study) were the dominant flying insects with aquatic larvae, and the presence / absence of forest greatly influenced which species were found (Fig. 7.1). Chironomidae dominated the hyporheic faunas at both sites where it was studied, and were almost certainly the major colonists colonising surface substrata via vertical migration. Nevertheless, the hyporheic zone was found to be of limited importance as a refuge in the intermittently flowing reach since it dried rapidly following the disappearance of surface flow.

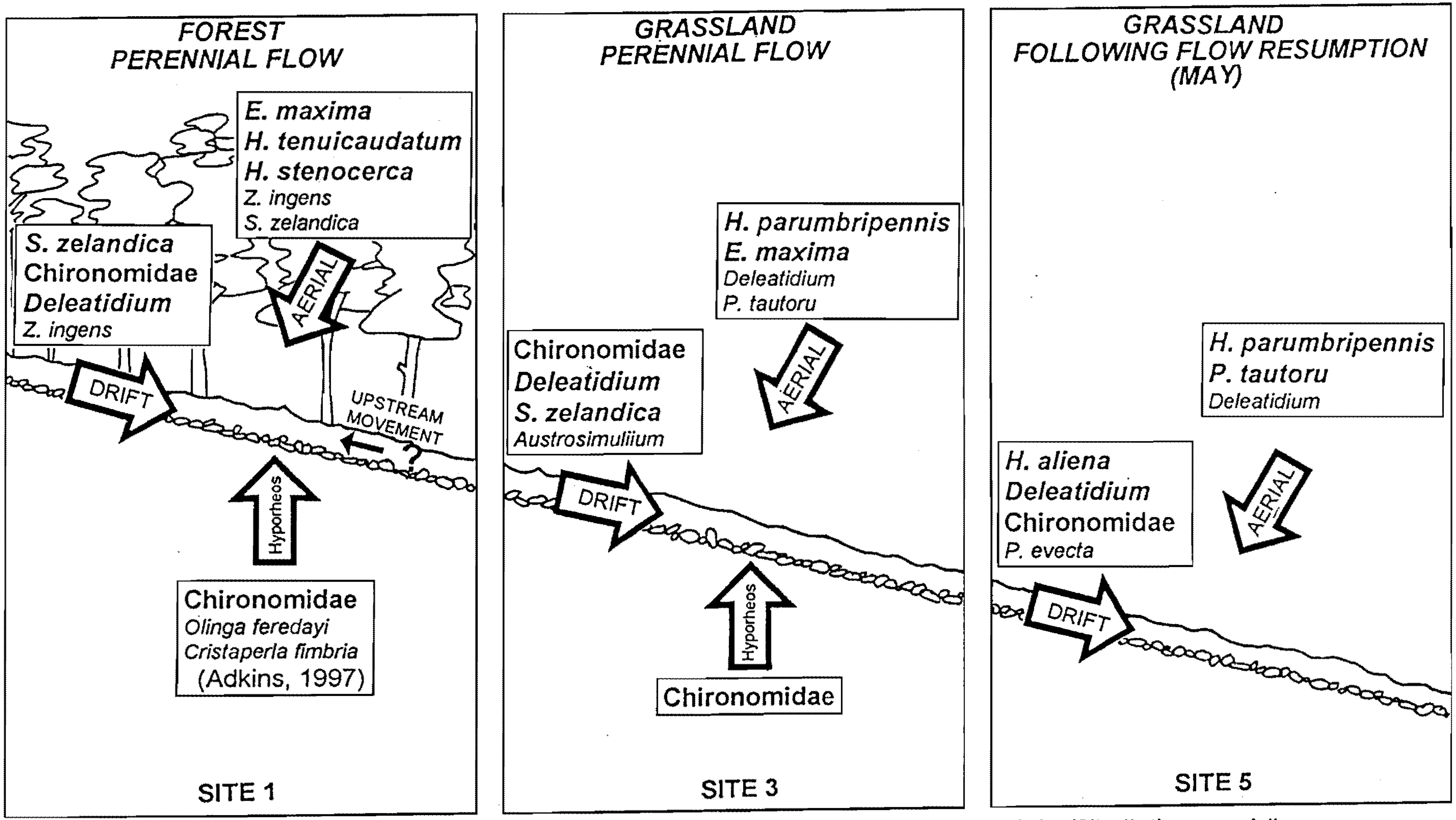


Fig. 7.1 Summary of colonisation pathways operating at the perennially flowing forested site (Site 1), the perennially flowing grassland site (Site 3), and the intermittently flowing grassland site (Site 5), of Middle Bush Stream. The dominant taxa utilising each pathway are listed, with the most abundant appearing in bold print.

Invertebrate drift from the perennially flowing upper reaches, and oviposition by aerial adults therefore appeared to be the main sources of colonists when flow resumed in the intermittent grassland reach of Middle Bush Stream (Fig. 7.1). Recolonisation of the benthos was gradual, as both drift and ovipositing adults contributed relatively low numbers of colonists in the late autumn and winter months following rewetting. Upstream migration was also of limited importance in recolonisation, since Middle Bush Stream rarely flowed directly into Grasmere Stream.

Many New Zealand stream invertebrates are ecological generalists, with flexible, poorly synchronised life-histories and a strong ability to colonise opportunistically and survive in a wide variety of disturbed environments (Winterbourn *et al.*, 1981). These adaptations are considered to have evolved in response to the highly disturbed and unpredictable stream environments that are common in the South Island of New Zealand (Winterbourn, 1997). Thus, many invertebrates are pre-adapted to intermittent flow conditions by life-cycle characteristics that allow recolonisation of bare substrate in most months of the year.

The gradual nature of recolonisation of the intermittent reach via drift and flight activity, further suggests that invertebrates inhabiting the reach were not specifically adapted to tolerate, or recover rapidly from, intermittent conditions. The temporally unpredictable nature of streambed drying, coupled with the proximity of permanent waters that contain large populations of potential colonists, have probably reduced selection pressure for invertebrate resistance in intermittent streams such as this. Instead, invertebrates appeared to be resilient, recolonising the reach from upstream and nearby permanent water sources. However, relatively low numbers of invertebrates colonised the reach of Middle Bush Stream by drift and flight in the months following flow resumption (compared with summer abundances), indicating that invertebrate life-histories were not specifically adapted to coincide with rewetting. This is not surprising considering the unpredictable timing of disturbances, including drying of the stream bed.

Previous studies of temporary streams have demonstrated that invertebrate colonisation pathways are dictated largely by local conditions

Table 7.1 Macroinvertebrate recolonisation mechanisms in temporary streams (adapted from Paltridge *et al.*, 1997).

Study	Most significant source	Substratum type	Harshness of dry season	Proximity to permanent water
Present study, New Zealand	Drift from perennial upper reaches	Gravels and cobbles	Moderate: temperate zone, 292 mm rain during 3 month dry period	Perennial upper reaches, permanent streams in close proximity
Paltridge *et al.* (1997) Australia	Drift from perennial upper reaches	Sand	Severe: tropical zone, no rain	Perennial upper reaches, billabongs for 6 months
Morrison (1990) Scotland	Vertical migration from substratum	Cobbles	Moderate: temperate zone, 197 mm rain during 4 month drought	Lochs nearby, perennial lower reaches
Boulton (1989) Australia	Vertical migration from substratum	Cobbles (and rotting wood)	Moderate: temperate zone	Persistent pools
Carl (1989) Iraq	Aerial migration	Fine, unstable, shallow sand	Severe: no rain for 6 months	Perennial lower reaches, stagnant water-bodies nearby
Smith & Pearson (1987) Australia	Aerial migration	Bedrock, boulders	Moderate: tropical zone, no rain but cool temperatures	Perennial lower reaches 6 km downstream
MacArthur & Barnes (1985) USA	Drift from perennial upper reaches	Glacial sediments, cobbles	Severe: alpine flow, glacial, stream dry 6 months	Perennial upper reaches and perennial lower reaches within 300 m
Williams (1977) Canada	Vertical migration from substratum	Gravel and cobbles	Moderate: temperate zone, pools persisted	Perennial upper reaches, perennial lower reaches
Harrison (1966) Rhodesia	Aerial migration	Sand	Severe: no rain for 6 months	Permanent streams in vicinity

(Table 7.1). Paltridge *et al.* (1997) considered substratum type, harshness of the dry season, and proximity to permanent water, to be the primary environmental factors influencing recolonisation pathways. At Middle Bush Stream these three factors were largely responsible for the dominance of drift and aerial migration in the recolonisation of the intermittently flowing, grassland reach. Although the dry period was not long compared with those reported in some other studies (Table 7.1), the loosely packed, well-drained gravels and cobbles of the stream bed did not retain water after drying of the surface channel. This prevented survival of aquatic invertebrates within the substrate during the dry period, thus precluding vertical migration from the substrate as a viable colonisation pathway. The proximity of the intermittently flowing reach to permanent waters allowed both drift (from the perennially flowing upper reaches) and aerial migration to occur, however.

The strong influence of local conditions on recolonisation pathways in Middle Bush Stream, makes it inappropriate to use my findings to generalise about the relative importance of colonisation processes occurring in other New Zealand intermittent streams. However, substratum type and the effect this has on hyporheic drainage, and proximity to permanent water bodies, and therefore sources of colonists, were clearly important determinants of the colonistion pathways employed. Therefore, these factors need to be taken into consideration when making predictions about recolonisation pathways operating in other streams and rivers.

"It is more fun to talk with someone who doesn't use long, difficult words but rather short, easy words like "What about lunch?""

"Winnie-the-Pooh"

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APPENDIX I
BENTHIC SAMPLES

November

SITE

	1A	1B	1C	1D	2A	2B	2C	2D	3A	3B	3C	3D	4A	4B	4C	4D	5A	5B	5C	5D
Trichoptera																				
Beraeoptera roria																				
Helicopsyche sp.													1				1			
Hudsonema aliena														1			1			
Hudsonema amabilis														2			3			
Oeconesus maori																	1			
Olinga spp.	1	2	1				1											1		
Oxyethria albiceps																				
Philorheithrus agilis			2	4																
Pycnocentrella eruensis																				
Pycnocentria evecta																1	1			
Zelandopsyche ingens																				
Aoteapsyche colonica																1				
Costachorema sp.																				
Costachorema psaroptera																				
Edpercivalia maxima					1		1								2					1
Hydrobiosella stenocerca		1																		
Hydrobiosis spp.	2	5		1	1			1	1		1			1	1		1		1	
Hydrobiosis clavigera														1						
Hydrobiosis parumbripennis													1			1	2		1	
Hydrobiosis spatulata																2				
Hydrochorema crassicaudatum																				
Hydrochorema tenuicaudatum																				
Polyplectropus sp.																				
Psilochorema sp.													3	2	2	1	6			
Plecoptera																				
Austroperla cyrene							2													
Cristaperla fimbria																				
Spaniocerca zelandica			2	2	1	1	10	1							2		2			2
Stenoperla prasina																				
Zelandobius sp.	5	12	6	1	11	1	24	9			2					1	55		1	4
Zelandobius pilosus																				
Zelandoperla sp.							1													
Ephemeroptera																				
Austroclima jollyae																				
Coloburiscus humeralis																1				
Deleatidium spp.	11	12	37	10	66	11	51	34	12	12	33	35	63	33	100	83	62	44	61	76
Nesameletus sp.	2				7		1	6	1			1	5	2			4	1	1	1
Diptera																				
Aphrophila neozelandica																				
Austrosimuliium sp.	1				8	1		3	4		5	1	13	2	37	18	24		1	7
Ceratopogonidae	1		1																	
Chironomidae	20	37	36	6	23	31	86	26	15	3	56	31	6	10	17	17	58	30	20	34
Eriopterini sp. 1	1	2						1								1				
Eriopterini sp. 2			1																	
Hexatomini		1														1				
Limonia sp.																				
Muscidae	2	1															3			1
Nothodixa sp.		1															1			
Paradixa sp.																				
Oligochaeta		2	7	10	6	11	7	2	2		3	1	2	8	1	9	26	2	1	9
Coleoptera																				
Elmidae	1	1		1		1														
Hydraenidae	6	2	1	1	3		6	2								1			1	
Hydrophilidae																				
Scirtidae																				
Mollusca																				
Potamopyrgus antipodarum													4		3		1			
Crustacea																				
Ostracoda	5		11	16	4	9	15	1						3		2	1	1	1	
Acarina																				
Nematomorpha																				
Gordiidae																				
Platyhelminthes	8	3	2	24	7	2	3	2				1	1							
Mecoptera																				
Nannochorista philpotti																				
TOTAL INVERTEBRATES	66	82	107	76	138	68	208	88	35	15	100	70	99	65	165	140	253	79	89	135

December

	SITE							
	3A	3B	3C	3D	5A	5B	5C	5D
Trichoptera								
Beraeoptera roria								
Helicopsyche sp.								
Hudsonema aliena				3				1
Hudsonema amabilis								3
Oeconesus maori								
Olinga spp.			1					
Oxyethria albiceps								
Philorheithrus agilis								
Pycnocentrella eruensis						1		
Pycnocentria evecta								17
Zelandopsyche ingens				4				
Aoteapsyche colonica								
Costachorema sp.								
Costachorema psaroptera	1							
Edpercivalia maxima		1						
Hydrobiosella stenocerca							1	
Hydrobiosis spp.	2	6	3	6	1	1	1	4
Hydrobiosis clavigera								
Hydrobiosis parumbripennis						1		3
Hydrobiosis spatulata	1				1			
Hydrochorema crassicaudatum								
Hydrochorema tenuicaudatum								
Polyplectropus sp.								
Psilochorema sp.							1	3
Plecoptera								
Austroperla cyrene								
Cristaperla fimbria								
Spaniocerca zelandica	1	10		11			5	1
Stenoperla prasina								
Zelandobius sp.			2	7				
Zelandobius pilosus								5
Zelandoperla sp.								
Ephemeroptera								
Austroclima jollyae								
Coloburiscus humeralis								
Deleatidium spp.	14	11	9	15	15	22	34	35
Nesameletus sp.	3						1	
Diptera								
Aphrophila neozelandica								
Austrosimuliium sp.	2	1	2	10	1	3	5	28
Ceratopogonidae								
Chironomidae	24	105	44	115	18	14	121	52
Eriopterini sp. 1								
Eriopterini sp. 2				2				
Hexatomini								
Limonia sp.								
Muscidae		1	1					
Nothodixa sp.				3				
Paradixa sp.								
Sciomyzidae								
Stratiomyidae								
Zelandotipula sp.								
Oligochaeta	2	8	8	4	7	3	5	10
Coleoptera								
Elmidae				2				
Hydraenidae				3	1	1		1
Hydrophilidae			1					
Scirtidae				1				
Mollusca								
Potamopyrgus antipodarum								
Crustacea								
Ostracoda							6	
Acarina				1				
Nematomorpha								
Gordiidae								
Platyhelminthes	1		1	11				3
Mecoptera								
Nannochorista philpotti								
TOTAL INVERTEBRATES	51	143	72	198	44	46	180	166

January

	SITE							
	3A	3B	3C	3D	5A	5B	5C	5D
Trichoptera				no sample				
Beraeoptera roria								
Helicopsyche sp.					1			
Hudsonema aliena	1							
Hudsonema amabilis							2	2
Oeconesus maori								
Olinga spp.					2		1	1
Oxyethria albiceps								1
Philorheithrus agilis						1		
Pycnocentrella eruensis								
Pycnocentria evecta					1	1		1
Zelandopsyche ingens								
Aoteapsyche colonica								
Costachorema sp.								
Costachorema psaroptera			1					
Edpercivalia maxima	1				1			
Hydrobiosella stenocerca								1
Hydrobiosis spp.			2		2	1	2	2
Hydrobiosis clavigera								
Hydrobiosis parumbripennis			1		4		1	
Hydrobiosis spatulata					2			
Hydrochorema crassicaudatum								
Hydrochorema tenuicaudatum								
Polyplectropus sp.								
Psilochorema sp.						4	4	
Plecoptera								
Austroperla cyrene								
Cristaperla fimbria								
Spaniocerca zelandica		1	6		7	20	5	9
Stenoperla prasina								
Zelandobius spp.			3		2	1		
Zelandobius pilosus			1				2	
Zelandoperla sp.								
Ephemeroptera								
Austroclima jollyae								
Coloburiscus humeralis								
Deleatidium spp.	4		12		12	2	42	22
Nesameletus sp.							1	
Diptera								
Aphrophila neozelandica								
Austrosimuliium sp.	1		1		3		1	
Ceratopogonidae								
Chironomidae	53	1	52		33	17	31	12
Eriopterini sp. 1								
Eriopterini sp. 2								
Hexatomini								
Limonia sp.								
Muscidae			1		1	1		1
Nothodixa sp.								
Paradixa sp.								
Sciomyzidae								
Stratiomyidae								
Zelandotipula sp.								
Oligochaeta	1		3		3	5	6	3
Coleoptera								
Elmidae								
Hydraenidae					1	1	1	2
Hydrophilidae								
Scirtidae								
Mollusca								
Potamopyrgus antipodarum								
Crustacea								
Ostracoda								
Acarina								
Nematomorpha								
Gordiidae								
Platyhelminthes	2		2					
Mecoptera								
Nannochorista philpotti								
TOTAL INVERTEBRATES	63	2	85		75	54	99	57

February

	SITE																			
	1A	1B	1C	1D	2A	2B	2C	2D	3A	3B	3C	3D	4A	4B	4C	4D	5A	5B	5C	5D
Trichoptera				no																
Beraeoptera roria				sample																
Helicopsyche sp.													1							
Hudsonema aliena																				
Hudsonema amabilis																				
Oeconesus maori																				
Olinga spp.		2	3							1										
Oxyethria albiceps											1					1				
Philorheithrus agilis	2		1		1		1						1							
Pycnocentrella eruensis																				
Pycnocentria evecta														2	1	2	2			
Zelandopsyche ingens					1								1		1					
Aoteapsyche colonica																				
Costachorema sp.									1	1										
Costachorema psaroptera																	1			
Edpercivalia maxima																				
Hydrobiosella stenocerca										1										
Hydrobiosis spp.		1						1		4			1	2		1				
Hydrobiosis clavigera																2				
Hydrobiosis parumbripennis										1			1							
Hydrobiosis spatulata																				
Hydrochorema crassicaudatum								1	1	1										
Hydrochorema tenuicaudatum																				
Polyplectropus sp.																				
Psilochorema sp.													3		1	1				
Plecoptera																				
Austroperla cyrene					1															
Cristaperla fimbria																				
Spaniocerca zelandica	7	3			1	1	1	3	2	2		2	1			1				
Stenoperla prasina																				
Zelandobius spp.	8	5	7		2	4	3	11	1	1	1	2				1				
Zelandobius pilosus																				
Zelandoperla sp.																				
Ephemeroptera																				
Austroclima jollyae																				
Coloburiscus humeralis																				
Deleatidium spp.	22	21	11		42	6	14	17	3	3	3	2	10	1	3	10	1			
Nesameletus sp.					1			1	2		1							1		
Diptera																				
Aphrophila neozelandica																				
Austrosimuliium sp.						1	3	17	2											
Ceratopogonidae																				
Chironomidae	42	32	18		37	21	17	5	70	102	32	25	38	8	15	11	4			6
Eriopterini sp. 1						1	1										1			
Eriopterini sp. 2	3	1												1						
Hexatomini		1									1									
Limonia sp.																				
Muscidae										3	1	1		2						
Nothodixa sp.													1							
Paradixa sp.																				
Sciomyzidae																				
Stratiomyidae	4	4	8					1	1											
Oligochaeta	16	16	11		10		2	1	1	2		2	8	10	9	2	7	7	3	5
Coleoptera																				
Elmidae	3						1	4							1	1				
Hydraenidae	2	2	2		1				3			1			1	2				
Hydrophilidae																				
Scirtidae																				
Mollusca																				
Potamopyrgus antipodarum									1	1			2			6		1	4	1
Crustacea																				
Ostracoda	67	38	20		23	9	18	11		6	5		42		18		3		13	
Acarina					1						1				1					
Nematomorpha																				
Gordiidae																				
Platyhelminthes			1		1	1	2	6	2											
Mecoptera																				
Nannochorista philpotti																				
TOTAL INVERTEBRATES	176	126	82		122	44	63	79	90	129	46	35	110	26	51	41	19	9	20	12

March

	SITE							
	3A	3B	3C	3D	5A	5B	5C	5D
Trichoptera					Stream bed dry			
Beraeoptera roria								
Helicopsyche sp.								
Hudsonema aliena								
Hudsonema amabilis								
Oeconesus maori								
Olinga spp.								
Oxyethira albiceps		1	1	1				
Philorheithrus agilis								
Pycnocentrella eruensis								
Pycnocentria evecta								
Zelandopsyche ingens								
Aoteapsyche colonica								
Costachorema sp.								
Costachorema psaroptera		1						
Edpercivalia maxima		1						
Hydrobiosella stenocerca								
Hydrobiosis spp.		5		2				
Hydrobiosis clavigera		2						
Hydrobiosis parumbripennis		2						
Hydrobiosis spatulata								
Hydrochorema crassicaudatum								
Hydrochorema tenuicaudatum								
Polyplectropus sp.								
Psilochorema sp.			1					
Plecoptera								
Austroperla cyrene								
Cristaperla fimbria								
Spaniocerca zelandica		1	3					
Stenoperla prasina								
Zelandobius sp.	3	17		6				
Zelandobius pilosus								
Zelandoperla sp.								
Ephemeroptera								
Austroclima jollyae								
Coloburiscus humeralis								
Deleatidium spp.	14	65	2	1				
Nesameletus sp.	1	2						
Diptera								
Aphrophila neozelandica								
Austrosimuliium sp.		1	1	5				
Ceratopogonidae								
Chironomidae	49	96	48	89				
Eriopterini sp. 1				1				
Eriopterini sp. 2								
Hexatomini								
Limonia sp.								
Muscidae								
Nothodixa sp.	2	1						
Paradixa sp.								
Oligochaeta	14	25	3	2				
Coleoptera								
Elmidae								
Hydraenidae	3	4						
Hydrophilidae								
Scirtidae								
Mollusca								
Potamopyrgus antipodarum								
Crustacea								
Ostracoda	1	3		4				
Acarina								
Nematomorpha								
Gordiidae								
Platyhelminthes		2						
Mecoptera								
Nannochorista philpotti		1	1					
TOTAL INVERTEBRATES	87	230	60	111				

April

	SITE							
	3A	3B	3C	3D	5A	5B	5C	5D
Trichoptera					Stream bed dry			
Beraeoptera roria								
Helicopsyche sp.								
Hudsonema aliena			5	3				
Hudsonema amabilis								
Oeconesus maori								
Olinga spp.								
Oxyethira albiceps			11					
Philorheithrus agilis		1						
Pycnocentrella eruensis								
Pycnocentria evecta			3					
Zelandopsyche ingens								
Aoteapsyche colonica								
Costachorema sp.								
Costachorema psaroptera								
Edpercivalia maxima			1					
Hydrobiosella stenocerca								
Hydrobiosis spp.	3	1	3					
Hydrobiosis clavigera								
Hydrobiosis parumbripennis			2					
Hydrobiosis spatulata								
Hydrochorema crassicaudatum								
Hydrochorema tenuicaudatum								
Polyplectropus sp.		1						
Psilochorema sp.								
Plecoptera								
Austroperla cyrene								
Cristaperla fimbria								
Spaniocerca zelandica		4	3					
Stenoperla prasina								
Zelandobius spp.	6	1	8					
Zelandobius pilosus			3					
Zelandoperla sp.								
Ephemeroptera								
Austroclima jollyae								
Coloburiscus humeralis			1					
Deleatidium spp.	14	25	11	4				
Nesameletus sp.		4						
Diptera								
Aphrophila neozelandica								
Austrosimulium sp.			1					
Ceratopogonidae								
Chironomidae	35	33	48	22				
Eriopterini sp. 1								
Eriopterini sp. 2								
Hexatomini				1				
Limonia sp.								
Muscidae			3					
Nothodixa sp.			1					
Paradixa sp.								
Oligochaeta	5	5	3	30				
Coleoptera								
Elmidae								
Hydraenidae			3	1				
Hydrophilidae								
Scirtidae								
Mollusca								
Potamopyrgus antipodarum		1						
Crustacea								
Ostracoda	8		1	4				
Acarina								
Nematomorpha								
Gordiidae								
Platyhelminthes		10						
Mecoptera								
Nannochorista philpotti				1				
TOTAL INVERTEBRATES	71	86	111	66				

May

	SITE							
	3A	3B	3C	3D	5A	5B	5C	5D
Trichoptera								
Beraeoptera roria								
Helicopsyche sp.								
Hudsonema aliena				1	1			1
Hudsonema amabilis		1						
Oeconesus maori				1				
Olinga spp.								
Oxyethira albiceps				1				
Philorheithrus agilis								
Pycnocentrella eruensis								
Pycnocentria evecta	1	12						
Zelandopsyche ingens								
Aoteapsyche colonica								
Costachorema sp.	1		1					
Costachorema psaroptera								
Edpercivalia maxima		1						
Hydrobiosella stenocerca								
Hydrobiosis spp.	5	1	4	3				
Hydrobiosis clavigera								
Hydrobiosis parumbripennis								
Hydrobiosis spatulata		1						
Hydrochorema crassicaudatum								
Hydrochorema tenuicaudatum								
Polyplectropus sp.		1		2				
Psilochorema sp.		4		2	1			
Plecoptera								
Austroperla cyrene								
Cristaperla fimbria								
Spaniocerca zelandica		6		1	3			
Stenoperla prasina								
Zelandobius spp.	10	6	2	4	1		1	
Zelandobius pilosus					2	2		
Zelandoperla sp.								
Ephemeroptera								
Austroclima jollyae								
Coloburiscus humeralis								
Deleatidium spp.	38	60	22	20	1	3	1	
Nesameletus sp.				1				
Diptera								
Aphrophila neozelandica				1				
Austrosimuliium sp.	1	11		1	1			
Ceratopogonidae								
Chironomidae	83	108	91	52	5	5	6	1
Eriopterini sp. 1								
Eriopterini sp. 2								
Hexatomini							1	
Limonia sp.								
Muscidae			2					
Nothodixa sp.								
Paradixa sp.								
Oligochaeta	41	13	39	47	11	27	25	37
Coleoptera								
Elmidae								
Hydraenidae	1		1	2		1		
Hydrophilidae								
Scirtidae	1			1				
Mollusca								
Potamopyrgus antipodarum		2						
Crustacea								
Ostracoda	8	6	5	10		1	3	
Acarina								
Nematomorpha								
Gordiidae								
Platyhelminthes	5	2	2	1				
Mecoptera								
Nannochorista philpotti								
TOTAL INVERTEBRATES	195	235	169	151	26	39	37	39

June

SITE

	1A	1B	1C	1D	2A	2B	2C	2D	3A	3B	3C	3D	4A	4B	4C	4D	5A	5B	5C	5D
Trichoptera																				
Beraeoptera roria																				
Helicopsyche sp.														1						
Hudsonema aliena					1			1									2			1
Hudsonema amabilis													4	16	16	5				
Oeconesus maori					2			2					4	9	10	3			1	
Olinga spp.			1										2	4	4	1				
Oxyethira albiceps														1						
Philorheithrus agilis																				
Pycnocentrella eruensis																				
Pycnocentria evecta	2						1	1		1	1	19	21	18	5	35				2
Zelandopsyche ingens																				
Aoteapsyche colonica																				
Costachorema sp.																				
Costachorema psaroptera																				
Edpercivalia maxima	2		1				2													
Hydrobiosella stenocerca																				
Hydrobiosis spp.	6	1	1			1			10	7	4	1				1	1	2		6
Hydrobiosis clavigera																				
Hydrobiosis parumbripennis												1		1						1
Hydrobiosis spatulata	1		1								1								1	
Hydrochorema crassicaudatum			1												1					
Hydrochorema tenuicaudatum																				
Polyplectropus sp.																				
Psilochorema sp.												8	4	5	1	8				
Plecoptera																				
Austroperla cyrene								1				1		1						
Cristaperla fimbria																				
Spaniocerca zelandica	1	8	4		4	1	1	1		2	8	4					4			1
Stenoperla prasina								1												
Zelandobius spp.	1			3	4	3	10	7	10			5	3		1		1		1	6
Zelandobius pilosus									1			7	3	4	2	1	4	11	6	24
Zelandoperla sp.																				
Ephemeroptera																				
Austroclima jollyae														1						
Coloburiscus humeralis											2					3				
Deleatidium spp.	17	12	26	9	6	32	13	41	75	70	61	53	34	63	44	142	21	6	5	16
Nesameletus sp.		2			1			3					2	5	20	5			7	2
Diptera																				
Aphrophila neozelandica																				
Austrosimulium sp.					1	6	2		6	4	4	1	1			1		8	4	
Ceratopogonidae	1																			
Chironomidae	36	47	49	18	5	37	13	32	93	60	28	144	9	26	29	14	37	8	15	20
Eriopterini sp. 1				2																1
Eriopterini sp. 2																				
Hexatomini		1	2										2	1	1			1	1	
Limonia sp.																2				
Muscidae										1		1								1
Nothodixa sp.					1	3	2													
Paradixa sp.																				
Oligochaeta	158	41	24	38	3	3	1	8	70	11	17	35	4	14	16	13	14	49	44	17
Coleoptera																				
Elmidae							1													
Hydraenidae	2		1			2	1		1			1				1	1			1
Hydrophilidae																				
Ptilodactylidae				2																
Scirtidae	7	1	1				1													
Mollusca																				
Potamopyrgus antipodarum													1	1	1	2				
Crustacea																				
Ostracoda	113	86	58	31	23	39	14	21	8	6	4	50	26	42	59	33	1	1		
Acarina																1				
Nematomorpha																				
Gordiidae																				
Platyhelminthes		6	9	4	2	2	5	23	3											
Mecoptera																				
Nannochorista philpotti																				
TOTAL INVERTEBRATES	347	205	179	107	53	129	67	142	277	162	130	331	120	213	210	271	86	86	85	99

July

	SITE							
	3A	3B	3C	3D	5A	5B	5C	5D
Trichoptera								
Beraeoptera roria								
Helicopsyche sp.								1
Hudsonema aliena							1	
Hudsonema amabilis								
Oeconesus maori								
Olinga spp.								
Oxyethria albiceps					1			
Philorheithrus agilis								
Pycnocentrella eruensis								
Pycnocentria evecta	3	3	2				1	
Zelandopsyche ingens								
Aoteapsyche colonica								
Costachorema sp.								
Costachorema psaroptera								
Edpercivalia maxima		1						
Hydrobiosella stenocerca								
Hydrobiosis spp.		1	4		1	2		1
Hydrobiosis clavigera								
Hydrobiosis parumbripennis				1			1	
Hydrobiosis spatulata					1			
Hydrochorema crassicaudatum	1	4						
Hydrochorema tenuicaudatum								
Polyplectropus spp.								
Psilochorema spp.	3	3	2					1
Plecoptera								
Austroperla cyrene								
Cristaperla fimbria								
Spaniocerca zelandica	3	1	1	1			1	1
Stenoperla prasina								
Zelandobius spp.	5	3	8			3		1
Zelandobius pilosus	2	3	2	1	3	2	7	6
Zelandoperla sp.								
Ephemeroptera								
Austroclima jollyae								
Coloburiscus humeralis								
Deleatidium spp.	76	58	75	12	7	14	27	14
Nesameletus sp.					6	1		
Diptera								
Aphrophila neozelandica								
Austrosimulium sp.	2			2	2	10	8	
Ceratopogonidae								
Chironomidae	82	80	95	6	38	9	67	10
Eriopterini sp. 1								
Eriopterini sp. 2								
Hexatomini								
Limonia sp.								
Muscidae		1			1			
Nothodixa sp.								
Paradixa sp.								
Oligochaeta	14	35	56	1	61	9	16	11
Coleoptera								
Elmidae								
Hydraenidae	1						6	1
Hydrophilidae								
Ptilodactylidae								
Scirtidae	1		1					
Mollusca								
Potamopyrgus antipodarum					1			
Crustacea								
Ostracoda	7		4			1		1
Acarina								
Nematomorpha								
Gordiidae								
Platyhelminthes	1	1	1			1		
Mecoptera								
Nannochorista philpotti								
TOTAL INVERTEBRATES	201	194	251	24	122	52	135	48

August

	SITE							
	3A	3B	3C	3D	5A	5B	5C	5D
Trichoptera								
Beraeoptera roria								
Helicopsyche sp.								
Hudsonema aliena						1		
Hudsonema amabilis					1			
Oeconesus maori								
Olinga spp.								
Oxyethria albiceps								
Philorheithrus agilis								
Pycnocentrella eruensis								
Pycnocentria evecta	1			2				
Zelandopsyche ingens								
Aoteapsyche colonica						2	2	
Costachorema sp.								
Costachorema psaroptera								
Edpercivalia maxima						1		
Hydrobiosella stenocerca								
Hydrobiosis sp.	1			1		1		2
Hydrobiosis clavigera								
Hydrobiosis parumbripennis						2		
Hydrobiosis spatulata	1		1					
Hydrochorema crassicaudatum								
Hydrochorema tenuicaudatum								
Polyplectropus sp.								
Psilochorema sp.					1			1
Plecoptera								
Austroperla cyrene								
Cristaperla fimbria								
Spaniocerca zelandica		2	3	4	1	1	1	1
Stenoperla prasina								
Zelandobius spp.	2	5		10		2		
Zelandobius pilosus						4	2	1
Zelandoperla sp.								
Ephemeroptera								
Austroclima jollyae								
Coloburiscus humeralis				1	1	3	1	
Deleatidium spp.	31	21	20	88	30	57	48	30
Nesameletus sp.				1	4			
Diptera								
Aphrophila neozelandica								
Austrosimuliium sp.			11	1		4	3	5
Ceratopogonidae								
Chironomidae	14	14	15	38	25	21	15	15
Eriopterini sp. 1								
Eriopterini sp. 2								
Hexatomini								
Limonia sp.						1		
Muscidae					1			
Nothodixa sp.						1		
Paradixa sp.								
Oligochaeta	1			4	3	8		15
Coleoptera								
Elmidae								
Hydraenidae						1		
Hydrophilidae								
Scirtidae								
Mollusca								
Potamopyrgus antipodarum								
Crustacea								
Ostracoda	1	2		1	1	1		2
Acarina								
Nematomorpha								
Gordiidae								
Platyhelminthes	2		1	1				
Mecoptera								
Nannochorista philpotti								
TOTAL INVERTEBRATES	54	44	51	152	68	111	72	72

September

	SITE																			
	1A	1B	1C	1D	2A	2B	2C	2D	3A	3B	3C	3D	4A	4B	4C	4D	5A	5B	5C	5D
Trichoptera																				
Beraeoptera roria																				
Helicopsyche sp.																				
Hudsonema aliena													1							
Hudsonema amabilis																				
Oeconesus maori																				
Olinga spp.		2			1			1						2						
Oxyethria albiceps																				
Philorheithrus agilis																				
Pycnocentrella eruensis																				
Pycnocentria evecta	1												8	6	5		3	3		4
Zelandopsyche ingens	1	2			1	2														
Aoteapsyche colonica													5					1	1	
Costachorema sp.							1						1	1						
Costachorema psaroptera																				
Edpercivalia maxima					1				2											
Hydrobiosella stenocerca				1																
Hydrobiosis spp.				2	2	3	1				1	1	2	1		1	1	1		
Hydrobiosis clavigera										1							1			
Hydrobiosis parumbripennis													1		1	1		2		1
Hydrobiosis spatulata										3		2								
Hydrochorema crassicaudatum																				
Hydrochorema tenuicaudatum						1														
Polyplectropus sp.																				
Psilochorema sp.													2	2						
Plecoptera																				
Austroperla cyrene																				
Cristaperla fimbria		8					1											1		
Spaniocerca zelandica		1	1									1		1		4	2	2	3	
Stenoperla prasina																				
Zelandobius spp.	1	1		3	1	4	3	7	1	4	2	1	5	2		1	1	1		
Zelandobius pilosus										1			1				3	2		
Zelandoperla sp.								1												
Ephemeroptera																				
Austroclima jollyae																				
Coloburiscus humeralis													10	7	1	3	1	6	1	
Deleatidium spp.	16	19	17	21	10	65	54	52	41	34	54	35	122	109	97	108	46	52	36	56
Nesameletus sp.	1	1			2	1	4	1		3			1	2	1		1			
Diptera																				
Aphrophila neozelandica																				1
Austrosimulium sp.	2					5	1			1	2	2	8	4	5	12	7	8	2	3
Ceratopogonidae				1													1			
Chironomidae	29	19	10	47	5	14	4	2	2	24	4	4	14	11	8	16	34	28	29	7
Eriopterini sp. 1	1			3															2	
Eriopterini sp. 2						1														
Hexatomini																				
Limonia sp.																				
Muscidae																				
Nothodixa sp.						1														
Paradixa sp.																				
Oligochaeta	16	17	6	12	1	3	2		2	12	2		3	10	1	4	9	7	16	3
Coleoptera																				
Elmidae															1					
Hydraenidae		3		2		1	1			1					1		1			1
Hydrophilidae																				
Ptilodactylidae																				
Scirtidae		3																1		
Mollusca																				
Potamopyrgus antipodarum														1			2			
Crustacea																				
Ostracoda	17	25	3	56	16	7	22	4		5			4	8	7	6	6	6	3	
Acarina																				
Nematomorpha																				
Gordiidae																				
Platyhelminthes	5	8	2	5	2	7	2	6		2	1		1		1			1		
Mecoptera																				
Nannochorista philpotti																				
TOTAL INVERTEBRATES	90	109	39	153	42	115	98	74	48	91	66	46	189	167	129	156	119	122	93	76

October

	SITE							
	3A	3B	3C	3D	5A	5B	5C	5D
Trichoptera								
Beraeoptera roria	1							
Helicopsyche sp.								
Hudsonema aliena				1				1
Hudsonema amabilis						1		1
Oeconesus maori					1			
Olinga spp.								
Oxyethria albiceps								
Philorheithrus agilis								
Pycnocentrella eruensis								
Pycnocentria evecta			1		2	5		6
Zelandopsyche ingens	1							
Aoteapsyche colonica						2	2	
Costachorema sp.					1			
Costachorema psaroptera								
Edpercivalia maxima				1	1			1
Hydrobiosella stenocerca							1	
Hydrobiosis spp.	5	2	1	1		1	2	
Hydrobiosis clavigera	1				1			
Hydrobiosis parumbripennis					2	3		1
Hydrobiosis spatulata	1		1	1				
Hydrochorema crassicaudatum								
Hydrochorema tenuicaudatum								
Polyplectropus sp.								
Psilochorema sp.								
Plecoptera								
Austroperla cyrene								
Cristaperla fimbria								
Spaniocerca zelandica		1	2		1	10		3
Stenoperla prasina								
Zelandobius spp.	2	2	4			1		
Zelandobius pilosus					2	6	2	5
Zelandoperla sp.								
Ephemeroptera								
Austroclima jollyae								
Coloburiscus humeralis					7	4	1	2
Deleatidium spp.	71	54	38	30	70	187	69	103
Nesameletus sp.	4	1				1		
Diptera								
Aphrophila neozelandica								
Austrosimuliium sp.			1	1		30		3
Ceratopogonidae								
Chironomidae	108	20	17	27	65	98	37	67
Eriopterini sp. 1								
Eriopterini sp. 2								
Hexatomini				1				
Limonia sp.								
Muscidae								1
Nothodixa sp.						1		
Paradixa sp.								
Oligochaeta	19	1	5		4	4	18	10
Coleoptera								
Elmidae								
Hydraenidae	2			4		2		2
Hydrophilidae								
Scirtidae								
Mollusca								
Potamopyrgus antipodarum					1			1
Crustacea								
Ostracoda	8	5		2	12		1	2
Acarina								
Nematomorpha								
Gordiidae								
Platyhelminthes	3	5	1	9		3		2
Mecoptera								
Nannochorista philpotti								
TOTAL INVERTEBRATES	226	91	71	78	170	359	133	211

DRIFT SAMPLES

November

SITE

	1A	1B	1C	2A	2B	2C	3A	3B	3C	4A	4B	4C	5A	5B	5C
Trichoptera															
Beraeoptera roria									No	1		No	1		
Helicopsyche sp.									sample			sample			
Hudsonema aliena					1	1				14	14		8	37	36
Hudsonema amabilis										6	1		1	4	3
Oeconesus maori			6								3				
Olinga spp.	1	4	2			1									
Oxyethira albiceps															
Philorheithrus agilis		4	2			1									
Pycnocentrella eruensis															
Pycnocentria evecta										12	2		3	4	1
Pycnocentria sylvestris		1													
Zelandopsyche ingens	6	5	1	2	5	9									
Aoteapsyche colonica										1			1	5	5
Costachorema sp.															
Costachorema psaroptera			1										1		1
Edpercivalia maxima	1	2	1	1	2	5	3	1		5	1			9	5
Hydrobiosella stenocerca			1		1			1		1	1		6	6	8
Hydrobiosis spp.	2	4	6		1	3							1	3	
Hydrobiosis clavigera										1					
Hydrobiosis parumbripennis										2	1		10	6	10
Hydrobiosis spatulata					2	1	1			1			3	12	1
Hydrochorema crassicaudatum															
Hydrochorema tenuicaudatum															
Polyplectropus sp.													1	1	1
Psilochorema spp.										3	2		4	12	7
Tiphobiosis sp.	2														
Plecoptera															
Acroperla spiniger															
Austroperla cyrene															
Cristaperla fimbria			1												
Spaniocerca zelandica	13	32	18	1	9	27	6	7		5	10		19	47	41
Stenoperla prasina															
Zelandobius spp.	1	1			1		1	1					1	2	3
Zelandobius pilosus	1				2	1	2	4		18	11		37	64	54
Zelandoperla sp.				1	1					1	2				2
Ephemeroptera															
Austroclima jollyae															
Coloburiscus humeralis											1			1	1
Deleatidium spp.	7	25	7	11	22	51	51	62		457	324		609	1108	1048
Nesameletus sp.	2	1		1	1			1		10	5		22	48	33
Oniscigaster distans														1	1
Diptera															
Austrosimulium sp.		1	1	1	5	13	4	5		61	37		122	145	134
Chironomidae	39	36	44	30	113	197	60	56		35	42		107	132	184
Eriopterini sp. 1															
Eriopterini sp. 2															
Limonia sp.															
Muscidae					1						1		1	2	3
Nothodixa sp.	1		6		1	7	4	1		4	2		6	14	7
Paradixa sp.															
Sciomyzidae															
Stratiomyidae								1							2
Zelandotipula sp.															
Oligochaeta	4	8	8	2	11	10	6			2	2			9	8
Coleoptera															
Dytiscidae															
Elmidae															
Hydraenidae	1	7	1			8	1			4	3			7	2
Hydrophilidae			1												1
Scirtidae	3	4	6			1	1			5	4		7	8	20
Mollusca															
Potamopyrgus antipodarum										1					
Crustacea															
Ostracoda	2	12		2		3	1								
Acarina			1		3										1
Nematomorpha															
Gordiidae															
Platyhelminthes	2		6		1									1	1
Mecoptera															
Nannochorista philpotti			1												
Neuroptera															
Kempynus sp.	1		2												
TOTAL INVERTEBRATES	89	147	123	52	183	339	141	140		650	469		971	1688	1624
FLOW m/s		0.5			0.25			0.25			0.5			1	

December

	SITE														
	1A	1B	1C	2A	2B	2C	3A	3B	3C	4A	4B	4C	5A	5B	5C
Trichoptera															
Beraeoptera roria															
Helicopsyche sp.															
Hudsonema aliena	1	1	1	2	4	6			1	9	4	7	1	7	3
Hudsonema amabilis												5	2	1	1
Oeconesus maori						2									
Olinga spp.	3	4	3		1	1									
Oxyethria albiceps												1			
Philorheithrus agilis	32	16	29		1	3									
Pycnocentrella eruensis															
Pycnocentria evecta			1						1		2	3	3	2	3
Pycnocentria sylvestris	1														
Zelandopsyche ingens	5	5	7	4	7	22									
Aoteapsyche colonica					1							1			
Costachorema sp.		1		1	2				5						
Costachorema psaroptera												1			3
Edpercivalia maxima	1	1	3	3	5	8	1			1	2		1	1	1
Hydrobiosella stenocerca			1		6	3	3	4	1		1	2	1	4	7
Hydrobiosis spp.	1	5	4		7	3	2	10	5	3	1	3	4	8	2
Hydrobiosis clavigera															
Hydrobiosis parumbripennis													2	2	
Hydrobiosis spatulata	1	1	1	1	3	8	3	3	5			2	1		
Hydrochorema crassicaudatum															
Hydrochorema tenuicaudatum															
Polyplectropus sp.															
Psilochorema spp.								1	2			2	1		1
Tiphobiosis sp.			1			7									
Plecoptera															
Acroperla spiniger															
Austroperla cyrene															1
Cristaperla fimbria	1														
Spaniocerca zelandica	36	69	64	3	58	49	4	6	11	1		5	5	2	2
Stenoperla prasina						1									
Zelandobius spp.		6			6	7	2								
Zelandobius pilosus			2	1	1		4	4	9	5	2	9	10	7	11
Zelandoperla sp.			1		2	3		1					2		
Ephemeroptera															
Austroclima jollyae															
Coloburiscus humeralis												1			
Deleatidium spp.	14	19	56	49	120	147	48	69	119	8	10	47	77	65	49
Nesameletus sp.		1	4	7	1	6					1			8	1
Oniscigaster distans				1											
Diptera															
Austrosimuliium sp.	2	5	5	2	54	60	4	9	23	4	17	22	59	39	48
Chironomidae	16	30	41	7	358	386	80	103	119	12	17	36	38	59	61
Eriopterini sp. 1					1										
Eriopterini sp. 2															
Limonia sp.															
Muscidae					1	1		1	1			1			
Nothodixa sp.		2	1		14	14	2	1	10	2	1	1		1	
Paradixa sp.															
Sciomyzidae															
Stratiomyidae															
Zelandotipula sp.			1			1									
Oligochaeta	2	6	6	2	13	16	2	5	7		2	4	6	1	3
Coleoptera															
Dytiscidae															
Elmidae		1			1	1									
Hydraenidae	12	42	55		16	12			7		1	2	2	2	1
Hydrophilidae	1	1	1		1	1									
Scirtidae	8	4	8		9	11		1		1		1		3	2
Mollusca															
Potamopyrgus antipodarum															1
Crustacea															
Ostracoda			1												
Acarina		2				8			2	5	1	5		1	2
Nematomorpha															
Gordiidae		1	1		3	5			1			1	1	1	1
Platyhelminthes	3	7	7		17	20		1	2		1				
Mecoptera															
Nannochorista philpotti						1									
Neuroptera															
Kempynus sp.															
TOTAL INVERTEBRATES	140	230	305	83	713	813	155	219	331	51	63	162	216	214	204
FLOW m/s		0.456			0.314			0.216			0.439			0.299	

January

	SITE														
	1A	1B	1C	2A	2B	2C	3A	3B	3C	4A	4B	4C	5A	5B	5C
Trichoptera						No sample									
Beraeoptera roria											1				
Helicopsyche sp.													1		
Hudsonema aliena					2			3		8	6	1	19		13
Hudsonema amabilis											1				1
Oeconesus maori															
Olinga spp.			3										3		
Oxyethira albiceps															1
Philorheithrus agilis	3		1												
Pycnocentrella eruensis															
Pycnocentria evecta					1					1	7	3	100	1	49
Pycnocentria sylvestris															
Zelandopsyche ingens	2	4	1		2										
Aoteapsyche colonica				1							1		1		
Costachorema sp.					1			1							
Costachorema psaroptera								2		1					
Edpercivalia maxima			2		1					1			1	1	
Hydrobiosella stenocerca					2					2	2				4
Hydrobiosis spp.		1	6		2		1	5	3	6	6	1	2		7
Hydrobiosis clavigera															1
Hydrobiosis parumbripennis									1	5	4		2		7
Hydrobiosis spatulata	1		1					1							1
Hydrochorema crassicaudatum															
Hydrochorema tenuicaudatum															
Polyplectropus sp.															
Psilochorema spp.													1		3
Tiphobiosis sp.								1							
Plecoptera															
Acroperla spiniger															
Austroperla cyrene															
Cristaperla fimbria															
Spaniocerca zelandica	2	7	15		8		1	1	1	1	2		1	1	13
Stenoperla prasina															
Zelandobius spp.	1		4	2	2								5		
Zelandobius pilosus										1	2		2		13
Zelandoperla sp.													1		
Ephemeroptera															
Austroclima jollyae										1	1		3		1
Coloburiscus humeralis											1		1		
Deleatidium spp.	5	3	17		17		4	18	2	59	68	11	147	9	219
Nesameletus sp.					1					6			1		
Oniscigaster distans															
Diptera															
Austrosimulium sp.					9		6	13	9	8	6	3	3		3
Chironomidae	5	10	30	9	81		5	32	9	10	9	4	12	7	20
Eriopterini sp. 1															
Eriopterini sp. 2															
Limonia sp.															
Muscidae					2										
Nothodixa sp.	2				4				2		3	2	8	1	6
Paradixa sp.															
Sciomyzidae															
Stratiomyidae															
Zelandotipula sp.															
Oligochaeta		2	2							1			1		
Coleoptera															
Dytiscidae															
Elmidae															
Hydraenidae	1	1	2		8		1	2		4			13		17
Hydrophilidae			1		1										
Scirtidae	1				1								3		
Mollusca															
Potamopyrgus antipodarum															1
Crustacea															
Ostracoda															
Acarina	2	2			6			1					2		
Nematomorpha															
Gordiidae			1		1					1					
Platyhelminthes	1	4	5	1	11										
Mecoptera															
Nannochorista philpotti													1		
Neuroptera															
Kempynus sp.															
TOTAL INVERTEBRATES	26	34	91	13	163		18	80	27	116	120	25	334	20	380
FLOW m/s		0.100			0.200			0.250			0.250			0.250	

SITE

	1A	1B	1C	2A	2B	2C	3A	3B	3C	4A	4B	4C	5A	5B	5C
Trichoptera													Stream bed dry		
Beraeoptera roria															
Helicopsyche sp.															
Hudsonema aliena	1		1	3	2	2	3			2	6	7			
Hudsonema amabilis	1										2				
Oeconesus maori											1				
Olinga spp.	4	1	1							1	1	1			
Oxyethira albiceps							3		1	1	3				
Philorheithrus agilis	6		1			1									
Pycnocentrella eruensis															
Pycnocentria evecta			1							60	42	36			
Pycnocentria sylvestris								1							
Zelandopsyche ingens	4			5	3	4									
Aoteapsyche colonica				1								1			
Costachorema sp.					1							1			
Costachorema psaroptera															
Edpercivalia maxima	5			1	3	4	3	1							
Hydrobiosella stenocerca			1	1	1	2									
Hydrobiosis spp.	2	1	1	4	2	3	2		1	5	6	3			
Hydrobiosis clavigera										1		1			
Hydrobiosis parumbripennis										4	2	7			
Hydrobiosis spatulata				2	1										
Hydrochorema crassicaudatum															
Hydrochorema tenuicaudatum	1														
Polyplectropus sp.															
Psilochorema spp.										11	9	12			
Tiphobiosis sp.															
Plecoptera															
Acroperla spiniger															
Austroperla cyrene															
Cristaperla fimbria															
Spaniocerca zelandica	30	16	19	61	37	42	26	9	10	2	1	2			
Stenoperla prasina			2		1										
Zelandobius spp.	6	1		26	30	11	9	6	5		1				
Zelandobius pilosus			2		1										
Zelandoperla sp.	1				1										
Ephemeroptera															
Austroclima jollyae				1	3										
Coloburiscus humeralis															
Deleatidium spp.	4	4	3	134	105	76	20	15	11	6	18	25			
Nesameletus sp.					1	1				2	3	2			
Oniscigaster distans															
Diptera															
Austrosimulium sp.	2			9	6	7									
Chironomidae	41	15	28	205	199	167	104	70	46	32	66	43			
Eriopterini sp. 1															
Eriopterini sp. 2					1						1				
Limonia sp.															
Muscidae				2	1		4	4	1	3	2	2			
Nothodixa sp.	4	4		24	22	16	1	1	1	7	4				
Paradixa sp.															
Sciomyzidae												1			
Stratiomyidae															
Zelandotipula sp.															
Oligochaeta	7			7	5	2	5		3						
Coleoptera															
Dytiscidae															
Elmidae				1	1										
Hydraenidae	8		5	8	8	4			1						
Hydrophilidae	2		2	1											
Scirtidae	28	8	3	24	3	10				2	4	4			
Mollusca															
Potamopyrgus antipodarum															
Crustacea															
Ostracoda				3	1	1									
Acarina		1			8	3									
Nematomorpha															
Gordiidae	1	1		2											
Platyhelminthes			1	7	10										
Mecoptera															
Nannochorista philpotti															
Neuroptera															
Kempynus sp.															
TOTAL INVERTEBRATES	158	52	71	532	457	356	180	107	80	139	172	148			
FLOW m/s		0.082			0.198			0.000			0.000				

March

	SITE														
	1A	1B	1C	2A	2B	2C	3A	3B	3C	4A	4B	4C	5A	5B	5C
Trichoptera													Stream bed dry		
Beraeoptera roria															
Helicopsyche sp.															
Hudsonema aliena									1	3	1	1			
Hudsonema amabilis															
Oeconesus maori															
Olinga spp.	1	2													
Oxyethira albiceps											1				
Philorheithrus agilis															
Pycnocentrella eruensis															
Pycnocentria evecta						1				4					
Pycnocentria sylvestris															
Zelandopsyche ingens	1	1													
Aoteapsyche colonica															
Costachorema sp.															
Costachorema psaroptera															
Edpercivalia maxima	1														
Hydrobiosella stenocerca				1	1					1					
Hydrobiosis spp.		1		1		2				1	1				
Hydrobiosis clavigera															
Hydrobiosis parumbripennis												1			
Hydrobiosis spatulata				1		1		1							
Hydrochorema crassicaudatum															
Hydrochorema tenuicaudatum															
Polyplectropus sp.															
Psilochorema spp.															
Tiphobiosis sp.															
Plecoptera															
Acroperla spiniger															
Austroperla cyrene															
Cristaperla fimbria															
Spaniocerca zelandica		8	2	1		2									
Stenoperla prasina															
Zelandobius spp.	3				1	3			1	2		2			
Zelandobius pilosus															
Zelandoperla sp.			1												
Ephemeroptera															
Austroclima jollyae										1					
Coloburiscus humeralis											1				
Deleatidium spp.	3	4		1			1			3					
Nesameletus sp.															
Oniscigaster distans															
Diptera															
Austrosimuliium spp.		1	1	10	5	5	3	3	4						
Chironomidae	13	13	7	4	4	6	6	10	8	3	3	3			
Eriopterini sp. 1															
Eriopterini sp. 2															
Limonia sp.															
Muscidae											1				
Nothodixa sp.	2	1	2	5	2	3	2	1		6					
Paradixa sp.															
Sciomyzidae															
Stratiomyidae															
Zelandotipula sp.															
Oligochaeta		1													
Coleoptera															
Dytiscidae															
Elmidae	1														
Hydraenidae	1	2					2								
Hydrophilidae															
Scirtidae						1									
Mollusca															
Potamopyrgus antipodarum															
Crustacea															
Ostracoda															
Acarina															
Nematomorpha															
Gordiidae							3								
Platyhelminthes		1										1			
Mecoptera															
Nannochorista philpotti															
Neuroptera															
Kempynus sp.															
TOTAL INVERTEBRATES	26	35	13	24	13	24	17	15	14	24	8	8			
FLOW m/s	0.220			0.103			0.000			0.067					

April

	SITE														
	1A	1B	1C	2A	2B	2C	3A	3B	3C	4A	4B	4C	5A	5B	5C
Trichoptera													Stream bed dry		
Beraeoptera roria															
Helicopsyche sp.															
Hudsonema aliena						2	1			9	32	3			
Hudsonema amabilis											2				
Oeconesus maori											1				
Olinga spp.	3	1									2				
Oxyethria albiceps									1						
Philorheithrus agilis															
Pycnocentrella eruensis															
Pycnocentria evecta										14	41	3			
Pycnocentria sylvestris															
Zelandopsyche ingens			1	1											
Aoteapsyche colonica															
Costachorema sp.															
Costachorema psaroptera															
Edpercivalia maxima	3		1	1		2									
Hydrobiosella stenocerca			1												
Hydrobiosis spp.				3	1	2				1	3				
Hydrobiosis clavigera															
Hydrobiosis parumbripennis											2				
Hydrobiosis spatulata															
Hydrochorema crassicaudatum															
Hydrochorema tenuicaudatum															
Polyplectropus sp.															
Psilochorema spp.															
Tiphobiosis sp.															
Plecoptera															
Acroperla spiniger				2											
Austroperla cyrene															
Cristaperla fimbria															
Spaniocerca zelandica	7	1	3	2						3	1				
Stenoperla prasina															
Zelandobius spp.	5	4		5	9	14	1			3	7	11			
Zelandobius pilosus															
Zelandoperla sp.				1											
Ephemeroptera															
Austroclima jollyae															
Coloburiscus humeralis											5				
Deleatidium spp.	2	1	1	16	6	22				59	561	144			
Nesameletus sp.							1			15	111	11			
Oniscigaster distans															
Diptera															
Austrosimuliium sp.	1		2	3	1	5									
Chironomidae	6	10	12	3	4	4	1		2	5	7	3			
Eriopterini sp. 1															
Eriopterini sp. 2															
Limonia sp.															
Muscidae						3									
Nothodixa sp.			1	4	1	5				2	5	2			
Paradixa sp.										1					
Sciomyzidae															
Stratiomyidae															
Zelandotipula sp.															
Oligochaeta		1			1	1									
Coleoptera															
Dytiscidae															
Elmidae	1														
Hydraenidae				4	1	2		1			1	3			
Hydrophilidae															
Scirtidae	2	1			1					1	2	1			
Mollusca															
Potamopyrgus antipodarum										1	1				
Crustacea															
Ostracoda															
Acarina															
Nematomorpha															
Gordiidae	1									1		1			
Platyhelminthes			1	5	4	4									
Mecoptera															
Nannochorista philpotti															
Neuroptera															
Kempynus sp.															
TOTAL INVERTEBRATES	31	19	23	50	29	66	4	1	3	115	784	182			
FLOW m/s		0.196			0.121			0.000			0.000				

	SITE														
	1A	1B	1C	2A	2B	2C	3A	3B	3C	4A	4B	4C	5A	5B	5C
Trichoptera															
Beraeoptera roria															
Helicopsyche sp.															
Hudsonema aliena						1	26	25	1	9	8	12	6	3	3
Hudsonema amabilis											1				
Oeconesus maori															
Olinga spp.		1	1			1									
Oxyethira albiceps							1		2		1				
Philorheithrus agilis															
Pycncentrella eruensis															
Pycnocentria evecta				1		1		1		4	1	2			1
Pycnocentria sylvestris															
Zelandopsyche ingens			1	1		1									
Aoteapsyche colonica							1			1		1	1	1	1
Costachorema sp.							1								
Costachorema psaroptera		1													
Edpercivalia maxima			1		1	2		1							1
Hydrobiosella stenocerca		1			1							2	1	3	1
Hydrobiosis spp.	3		1			1	2	2		1	2	2	2	1	
Hydrobiosis clavigera															
Hydrobiosis parumbripennis													3		
Hydrobiosis spatulata	2				1			1	2						
Hydrochorema crassicaudatum															
Hydrochorema tenuicaudatum															
Polyplectropus sp.												1			
Psilochorema spp.											1	2			
Tiphobiosis sp.															
Plecoptera															
Acroperla spiniger															
Austroperla cyrene															
Cristaperla fimbria											2				
Spaniocerca zelandica	20	35	5	3	2	3	5	3	1		2	1		1	
Stenoperla prasina	1														
Zelandobius spp.	9	8	1	5	7	10	5	4							
Zelandobius pilosus							6		2	1	1	3			
Zelandoperla sp.															
Ephemeroptera															
Austroclima jollyae															
Coloburiscus humeralis											2	2			
Deleatidium spp.	7	17	4	13	22	27	8	13		13	8	3	3	3	4
Nesameletus sp.	4					1	1	2	1		1	1	3	1	4
Oniscigaster distans															
Diptera															
Austrosimuliium sp.		1		1	1	2	4	3	1		1	1			
Chironomidae	8	5	13	5	8	4	2	1			11	6	1	1	1
Eriopterini sp. 1															
Eriopterini sp. 2															
Limonia sp.	1					1		1							
Muscidae		3						2							
Nothodixa sp.	1	2	1	1	1	2	3		1	1	1		2		
Paradixa sp.													1		
Sciomyzidae															
Stratiomyidae															
Zelandotipula sp.															
Oligochaeta	6	3	2	2			1			1	2		1	4	1
Coleoptera															
Dytiscidae															
Elmidae															
Hydraenidae		6		3	5	1	6	4		1		1	3	1	3
Hydrophilidae													1		
Scirtidae	1	5			1	1									
Mollusca															
Potamopyrgus antipodarum															
Crustacea															
Ostracoda				2							4				
Acarina						1		1		1	1			2	
Nematomorpha															
Gordiidae							2					1		2	3
Platyhelminthes	2	3		3	2	3		1							
Mecoptera															
Nannochorista philpotti			1												
Neuroptera															
Kempynus sp.															
TOTAL INVERTEBRATES	65	91	31	40	52	63	74	65	11	33	50	41	28	23	23
FLOW m/s		0.237			0.147			0.176			0.289			0.351	

June

	SITE														
	1A	1B	1C	2A	2B	2C	3A	3B	3C	4A	4B	4C	5A	5B	5C
Trichoptera															
Beraeoptera roria										1					
Helicopsyche sp.															
Hudsonema aliena				1	2	1	2	3		3	5	6	6	2	2
Hudsonema amabilis										1		2			
Oeconesus maori										1					
Olinga spp.	1	1	2									1			
Oxyethria albiceps											1				
Philorheithrus agilis															
Pycnocentrella eruensis															
Pycnocentria evecta										4		3			
Pycnocentria sylvestris															
Zelandopsyche ingens		1	1	1		1									
Aoteapsyche colonica											1	3			
Costachorema sp.															
Costachorema psaroptera															
Edpercivalia maxima	1	1	1	1	4	1						3	1	1	1
Hydrobiosella stenocerca	2	2	2						1	3		1			
Hydrobiosis spp.	1	1		2	3	3		4		1	2	3			
Hydrobiosis clavigera															
Hydrobiosis parumbripennis									1		1	1			
Hydrobiosis spatulata	1	3		2	2	2			1	1					
Hydrochorema crassicaudatum						1									
Hydrochorema tenuicaudatum															
Polyplectropus sp.													1		
Psilochorema spp.						1		1		1	1	1			
Tiphobiosis sp.															
Plecoptera															
Acroperla spiniger															
Austroperla cyrene															
Cristaperla fimbria		3	6												
Spaniocerca zelandica	5	45	43	14	14	7	2	4	1	4	6	8	5	1	2
Stenoperla prasina		1													
Zelandobius spp.	2	9	8	13	12	16	7	1	3	1		3			
Zelandobius pilosus							4	2	2	4	1	5			
Zelandoperla sp.															
Ephemeroptera															
Austroclima jollyae				1		1									
Coloburiscus humeralis															1
Deleatidium spp.	6	19	26	35	41	45	16	3	6	25	22	42	26	5	7
Nesameletus sp.		2	6	1	1	1				11	16	24	6	4	2
Oniscigaster distans											1				
Diptera															
Austrosimulium sp.		1	1	2		4	2	6	1			1			
Chironomidae	3	23	13	14	7	36	9	7	5	10	9	15	3	2	
Eriopterini sp. 1											1				
Eriopterini sp. 2															
Limonia sp.	1			1			1			1			1		
Muscidae		1						1			1			1	
Nothodixa sp.	2	5	4	3	4	4	1	1				3	1		
Paradixa sp.															
Sciomyzidae															
Stratiomyidae															
Zelandotipula sp.						1									
Oligochaeta	3	3	4	7	2	6	1	2	1	6	2	14	3	2	2
Coleoptera															
Dytiscidae															
Elmidae		1													
Hydraenidae	1	4	4	10	4	8	1			7		6	11	1	
Hydrophilidae												1	1		
Scirtidae	2	12	4		1	1	2								
Mollusca															
Potamopyrgus antipodarum															
Crustacea															
Ostracoda	1		4			6					4	3			
Acarina															
Nematomorpha															
Gordiidae		1									1	2	2	1	
Platyhelminthes	2	29	2	3	1	5									
Mecoptera															
Nannochorista philpotti			2	1											
Neuroptera															
Kempynus sp.															
TOTAL INVERTEBRATES	34	168	133	112	98	151	48	35	22	85	75	151	67	20	17
FLOW m/s		0.373			0.280			0.299			0.598			0.712	

July

	SITE														
	1A	1B	1C	2A	2B	2C	3A	3B	3C	4A	4B	4C	5A	5B	5C
Trichoptera															
Beraeoptera roria															
Helicopsyche sp.															
Hudsonema aliena				2		1	2	5	4			2	2	2	2
Hudsonema amabilis															
Oeconesus maori										1	1				
Olinga spp.	3													1	
Oxyethria albiceps												1		1	
Philorheithrus agilis															
Pycnocentrella eruensis															
Pycnocentria evecta												1			
Pycnocentria sylvestris															
Zelandopsyche ingens	1	1													
Aoteapsyche colonica															
Costachorema sp.															
Costachorema psaroptera															
Edpercivalia maxima	1		1	2	2		1	2	1						
Hydrobiosella stenocerca															
Hydrobiosis spp.	2		1	1			2				1			1	
Hydrobiosis clavigera															
Hydrobiosis parumbripennis															1
Hydrobiosis spatulata	1			1		2	3	4	1		1				
Hydrochorema crassicaudatum															
Hydrochorema tenuicaudatum															
Polyplectropus sp.										1					
Psilochorema spp.	1											4			1
Tiphobiosis sp.															
Plecoptera															
Acroperla spiniger															
Austroperla cyrene															
Cristaperla fimbria															
Spaniocerca zelandica	12	7	1	7	6	5	5	10	3	2	2	6	1		
Stenoperla prasina															
Zelandobius spp.	10	1	2	12	2	2	7	3	2					1	
Zelandobius pilosus							1	1	4			5	1	1	
Zelandoperla sp.															
Ephemeroptera															
Austroclima jollyae															
Coloburiscus humeralis												1			
Deleatidium spp.	8	3		45	11	8	11	20	17	10	11	7	9	9	4
Nesameletus sp.	3			1			1			2	4	2	2	2	2
Oniscigaster distans				1											
Diptera															
Austrosimuliium sp.				11	4	3		3	2	3	1	4	3	3	1
Chironomidae	2	6	8	19	7	9	17	13	13	5	4	3	2	7	4
Eriopterini sp. 1															
Eriopterini sp. 2															
Limonia sp.							1								
Muscidae															
Nothodixa sp.				2		1	2		2		1	1	1	2	
Paradixa sp.															
Sciomyzidae															
Stratiomyidae															
Zelandotipula sp.															
Oligochaeta	1			2	1		2	4						4	1
Coleoptera															
Dytiscidae															
Elmidae															
Hydraenidae	4	1	1	11	2	6	5	3	3	3	1	3		2	
Hydrophilidae															
Scirtidae		1		1										1	
Mollusca															
Potamopyrgus antipodarum															
Crustacea															
Ostracoda	3			1	3	2					2	1			
Acarina										3			1		
Nematomorpha															
Gordiidae															
Platyhelminthes	3			8		3									
Mecoptera															
Nannochorista philpotti															
Neuroptera															
Kempynus sp.															
TOTAL INVERTEBRATES	55	20	14	127	38	42	60	68	52	30	29	41	22	37	16
FLOW m/s	0.305			0.179			0.109			0.551			0.431		

August

	SITE														
	1A	1B	1C	2A	2B	2C	3A	3B	3C	4A	4B	4C	5A	5B	5C
Trichoptera							not sampled								
Beraeoptera roria										1					1
Helicopsyche sp.															
Hudsonema aliena				1	1	2				38	14	24	11	31	39
Hudsonema amabilis										1	1				
Oeconesus maori															
Olinga spp.	2	2	2												
Oxyethria albiceps															
Philorheithrus agilis															
Pycnocentrella eruensis															
Pycnocentria evecta										1	1	2			
Pycnocentria sylvestris															
Triplectides obsoleta										1					
Zelandopsyche ingens	35	18	34	11	109	85				1					
Aoteapsyche colonica										9	4		2		1
Costachorema sp.															
Costachorema psaroptera						1									
Edpercivalia maxima			1		4	2							1	2	3
Hydrobiosella stenocerca		1	2		2					1			2	5	2
Hydrobiosis spp.	7	1	8	3	11	9				41	2	3	3	2	3
Hydrobiosis clavigera															
Hydrobiosis parumbripennis													2	2	
Hydrobiosis spatulata	1	3	1		6	2				2					1
Hydrochorema crassicaudatum											1				
Hydrochorema tenuicaudatum															
Polyplectropus sp.														1	
Psilochorema spp.		1			2					5	1	1	1	1	2
Tiphobiosis sp.														1	
Plecoptera															
Acroperla spiniger															
Austroperla cyrene															
Cristaperla fimbria															
Halticoperla viridans			1												
Spaniocerca zelandica	51	20	71	16	181	111				15	10		9	11	13
Stenoperla prasina															
Zelandobius spp.	9	11	11	3	26	16				9	9	2		1	
Zelandobius pilosus										41	11	14	5	14	22
Zelandoperla sp.			1												
Ephemeroptera															
Austroclima jollyae										3	1				
Coloburiscus humeralis										1	6	6	1	2	
Deleatidium spp.	29	20	39	7	74	51				35	17	3	34	32	50
Nesameletus sp.			1	1	2	4				10	3		2		2
Oniscigaster distans															
Diptera															
Austrosimuliium sp.		3	5	2	6	8				18	12	20	7	19	8
Chironomidae	15	7	20	6	49	43				14	10	15	11	26	17
Eriopterini sp. 1															
Eriopterini sp. 2															
Limonia sp.	1				1									1	
Muscidae															1
Nothodixa sp.	2		6		6	8					2	2	1	3	4
Paradixa sp.															
Sciomyzidae															
Stratiomyidae															
Zelandotipula sp.					1	1									
Oligochaeta	10	3	8	2	13	15				1	3		4	1	3
Coleoptera															
Dytiscidae															
Elmidae	2		1			2									
Hydraenidae	5	4	13		7	8				2	3	1		1	3
Hydrophilidae						1									
Scirtidae	6	2	15		11	1				2		1			1
Mollusca															
Potamopyrgus antipodarum										1					
Crustacea															
Ostracoda	16	5	9		4	2				2	1	1			
Acarina					1								1		
Nematomorpha															
Gordidae										2	1			1	1
Platyhelminthes	3		5	1	8	2				1					
Mecoptera															
Nannochorista philpotti	1	1				1									
Neuroptera															
Kempynus sp.															
TOTAL INVERTEBRATES	195	102	254	53	525	375				258	113	95	97	157	177
FLOW m/s		0.365			0.112						0.316			0.581	

September

	SITE														
	1A	1B	1C	2A	2B	2C	3A	3B	3C	4A	4B	4C	5A	5B	5C
Trichoptera															
Beraeoptera roria															
Helicopsyche sp.															
Hudsonema aliena				2	3			4		17	8	7	10	13	17
Hudsonema amabilis													1		
Oeconesus maori					1				1	1					
Olinga spp.	1	4	3	3	5										
Oxyethira albiceps											1		1	2	
Philorheithrus agilis					2										
Pycnocentrella eruensis															
Pycnocentria evecta	1									1	1		1	1	1
Pycnocentria sylvestris															
Triplectides obsoleta															
Zelandopsyche ingens	29	23	33	118	92	52	11	7	9	1		1	1		
Aoteapsyche colonica										1	1	2	1	1	
Costachorema sp.						1		1							
Costachorema psaroptera															
Edpercivalia maxima			3	4	1		2	1		1			3	1	
Hydrobiosella stenocerca					1					1	2		3	3	3
Hydrobiosis spp.	7	3	3	13	7	3	1	6	4		3		1	2	1
Hydrobiosis clavigera															
Hydrobiosis parumbripennis											1	2	1		1
Hydrobiosis spatulata	4		1	12	12	6	4	1	5	1	1				2
Hydrochorema crassicaudatum															
Hydrochorema tenuicaudatum															
Polyplectropus sp.													1		1
Psilochorema spp.										1	1	2			
Tiphobiosis sp.															
Plecoptera															
Acroperla spiniger				1									1		
Austroperla cyrene									1						
Cristaperla fimbria		2	6												
Spaniocerca zelandica	38	29	11	138	103	44	20	18	24	11	17	21	33	28	30
Stenoperla prasina															
Zelandobius spp.		4	2	26	20	4	4	7	4	1	1	2	1	1	2
Zelandobius pilosus									1	9	6		2	4	4
Zelandoperla sp.	10	2	2												
Ephemeroptera															
Austroclima jollyae															
Coloburiscus humeralis										5		2		1	1
Deleatidium spp.	19	15	18	89	110	26	25	41	27	25	23	20	14	12	21
Nesameletus sp.	5	8	2	7	11	6	3	1		2	1	1	1	2	
Oniscigaster distans															
Diptera															
Austrosimulium sp.				4	3	2	3	2	8	13	11	21	9	4	8
Chironomidae	16	14	6	101	78	30	17	20	17	21	18	14	24	30	46
Eriopterini sp. 1															
Eriopterini sp. 2	1			1											
Limonia sp.		1													
Muscidae															
Nothodixa sp.		2	1	11	3	7	2	3	1		2	1		1	2
Paradixa sp.															
Sciomyzidae															
Stratiomyidae															
Zelandotipula sp.															
Oligochaeta	9	2	1	21	24	10	7	11	9	2	2	3	7	1	1
Coleoptera															
Dytiscidae															3
Elmidae															
Hydraenidae	2	1	2	11	5	3		2	2		1				1
Hydrophilidae				1											
Scirtidae	10	1	6	10	13	5		1						1	1
Mollusca															
Potamopyrgus antipodarum															
Crustacea															
Ostracoda															
Acarina															
Nematomorpha															
Gordiidae															
Platyhelminthes															
Mecoptera															
Nannochorista philpotti															
Neuroptera															
Kempynus sp.								1							
TOTAL INVERTEBRATES	152	111	100	573	494	199	99	127	113	114	101	99	116	108	146
FLOW m/s		0.491			0.302			0.141			0.543			0.584	

October

	SITE														
	1A	1B	1C	2A	2B	2C	3A	3B	3C	4A	4B	4C	5A	5B	5C
Trichoptera															
Beraeoptera roria										2					
Helicopsyche sp.															
Hudsonema aliena	1			1	3	1	4	4	4	13	15	20	18	14	17
Hudsonema amabilis												2			1
Oeconesus maori								1							
Olinga spp.	4	5	4		1										
Oxyethria albiceps															
Philorheithrus agilis	2	2													
Pycnocentrella eruensis															
Pycnocentria evecta											2	2			
Pycnocentria sylvestris			1		1										
Triplectides obsoleta															
Zelandopsyche ingens	37	39	22	45	84	36	5	4	9		1				2
Aoteapsyche colonica			1				1					2		1	2
Costachorema sp.		1					1								1
Costachorema psaroptera															
Edpercivalia maxima		1	1		2			1	4					1	
Hydrobiosella stenocerca			1							1	1	1		1	
Hydrobiosis spp.	3	2	1	1	2	2	2	3		1		2	2	2	3
Hydrobiosis clavigera															
Hydrobiosis parumbripennis											1			1	1
Hydrobiosis spatulata	4	2	5	2	2	1	3	2	3				1		1
Hydrochorema crassicaudatum															
Hydrochorema tenuicaudatum															
Polyplectropus sp.															
Psilochorema spp.										1		2			
Tiphobiosis sp.															
Plecoptera															
Acroperla spiniger															
Austroperla cyrene															
Cristaperla fimbria	3	3	4												
Spaniocerca zelandica	17	18	14	27	46	21	15	10	12	8	4	8	18	35	21
Stenoperla prasina		1													
Zelandobius spp.	5	4	2	3	11	10								2	
Zelandobius pilosus										2			17	15	12
Zelandoperla sp.		3	2	2	7	1	1		2				1		
Ephemeroptera															
Austroclima jollyae				1	1		1		2						1
Coloburiscus humeralis											1	1			
Deleatidium spp.	50	63	57	50	146	54	25	25	22	41	39	39	60	102	79
Nesameletus sp.	9	15	5	11	28	4	3	1	1	1	1	3	1	1	1
Oniscigaster distans															
Diptera															
Austrosimulium sp.		1	1	2	4	2	2	1	3	1	2		23	27	27
Chironomidae	11	14	12	30	53	22	13	8	18	17	13	20	110	109	82
Eriopterini sp. 1															
Eriopterini sp. 2											1		1		
Limonia sp.															
Muscidae				1	1	1	1	2				4	5	2	4
Nothodixa sp.	1	2	3	3	3	1	9		1	1	1	1			1
Paradixa sp.															
Sciomyzidae															
Stratiomyidae															
Zelandotipula sp.	1														
Oligochaeta	2	7	5	8	18	7	6	2	4	1	1	3	3	2	1
Coleoptera															
Dytiscidae															
Elmidae					1										
Hydraenidae	8	8	11	11	20	3	4	2	3		2	2		1	
Hydrophilidae							1								
Scirtidae	6	8	4	5	8						1	1			
Mollusca															
Potamopyrgus antipodarum															
Crustacea															
Ostracoda			4	6	5		2			1		1	1		
Acarina				2	3	1			1			4	4		
Nematomorpha															
Gordiidae			1		3				2						
Platyhelminthes	8	11	12	5	5	5						1			
Mecoptera															
Nannochorista philpotti	1	2	1		2				1						
Neuroptera															
Kempynus sp.							1								
TOTAL INVERTEBRATES	173	212	174	216	460	172	100	66	92	91	86	119	265	316	257
FLOW m/s		0.535			0.228			0.428			0.633			0.540	

APPENDIX III

HYPORHEIC SAMPLES

November	SITE 3 (wet)									SITE 5 (wet)								
	[illegible]	[illegible]	[illegible]	10-20A	10-20B	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	10-20A	10-20B	10-20C	[illegible]	[illegible]	[illegible]
Trichoptera																		
Beraeoptera roria																		
Helicopsyche sp.																		
Hudsonema aliena																		
Hudsonema amabilis																		
Oeconesus maori																		
Olinga spp.																1	1	
Oxyethria albiceps																		
Philorheithrus agilis												1						
Pycnocentria evecta																		
Pycnocentria funerea																		
Zelandopsyche ingens																		
Edpercivalia maxima			2		2		1	1										
Hydrobiosella stenocerca			1															
Hydrobiosis spp.			1															
Hydrobiosis parumbripennis		1	2															
Hydrobiosis spatulata																		
Hydrochorema crassicaudatum																		
Hydrochorema tenuicaudatum																		
Plectrocnemia sp.																		
Polyplectropus sp.	1																	
Psilochorema spp.				1	2											1		
Plecoptera																		
Austroperla cyrene																		
Cristaperla fimbria																		
Spaniocerca zelandica	7	2	3		2			1	1	1	1							4
Stenoperla prasina																		
Zelandobius spp.																		
Zelandobius pilosus																		
Ephemeroptera																		
Austroclima jollyae																		
Coloburiscus humeralis																		
Deleatidium spp.		1			3	1	2		1		1							
Nesameletus sp.																		
Diptera																		
Austrosimulium sp.																		
Ceratopogonidae																	1	
Chironomidae	200	74	172	39	62	20	87	30	72	73	49	44	14	20	16	5	29	15
Eriopterini sp. 1	1																	
Eriopterini sp. 2																		
Hexatomini																		
Muscidae																		
Nothodixa sp.	2			1											1			
Paradixa sp.																		
Oligochaeta			1		1							1					1	
Coleoptera																		
Elmidae																		
Hydraenidae																		
Hydrophilidae																		
Scirtidae																		
Mollusca																		
Potamopyrgus antipodarum																		
Crustacea																		
Ostracoda																		
Acarina																		
Nematomorpha																		
Gordiidae																		
Platyhelminthes																		
Mecoptera																		
Nannochorista philpotti																		
TOTAL INVERTEBRATES	211	78	182	41	72	21	90	32	74	74	51	46	14	20	17	7	32	19

December

	SITE 3 (wet)									SITE 5 (wet)								
	0-10A	0-10B	0-10C	10-20A	10-20B	10-20C	20-30A	20-30B	20-30C	0-10A	0-10B	0-10C	10-20A	10-20B	10-20C	20-30A	20-30B	20-30C
Trichoptera																		
Beraeoptera roria																		
Helicopsyche sp.												1						
Hudsonema aliena																		
Hudsonema amabilis											1							
Oeconesus maori											1	1					2	
Olinga spp.											2				1		1	
Oxyethria albiceps																		
Philorheithrus agilis				1						1					1			
Pycnocentria evecta											1	3					1	
Pycnocentria funerea																		
Zelandopsyche ingens																		
Edpercivalia maxima			1						1									
Hydrobiosella stenocerca																		
Hydrobiosis spp.																		
Hydrobiosis parumbripennis																		
Hydrobiosis spatulata																		
Hydrochorema crassicaudatum																		
Hydrochorema tenuicaudatum																		
Plectrocnemia sp.																		
Polyplectropus sp.								1		1								
Psilochorema spp.	1									5	4			1	1		2	
Plecoptera																		
Austroperla cyrene																		
Cristaperla fimbria																		
Spaniocerca zelandica		4	5			1		1		7	3	7	1		5		9	
Stenoperla prasina																		
Zelandobius spp.																		
Zelandobius pilosus																		
Ephemeroptera																		
Austroclima jollyae																		
Coloburiscus humeralis																		
Deleatidium spp.	3								1	4	5	5	1			1	4	
Nesameletus sp.																		
Diptera																		
Austrosimuliium sp.																		
Ceratopogonidae																		
Chironomidae	178	101	69	40	29	37	68	122	7	50	34	111	18	35	40	22	50	4
Eriopterini sp. 1																		
Eriopterini sp. 2																		
Hexatomini					1													
Muscidae			1															
Nothodixa sp.							1											
Paradixa sp.																		
Oligochaeta		2						1	1		1	1	1				1	
Coleoptera																		
Elmidae																	2	
Hydraenidae											1				1			
Hydrophilidae																		
Scirtidae																		
Mollusca																		
Potamopyrgus antipodarum	2	1									3	2						
Crustacea																		
Ostracoda							1	1										
Acarina							1	1										
Nematomorpha																		
Gordiidae																		
Platyhelminthes																		
Mecoptera																		
Nannochorista philpotti																		
TOTAL INVERTEBRATES	184	108	76	41	30	38	71	127	10	68	56	131	21	36	49	23	72	4

January

	SITE 3 (wet)									SITE 5 (drying began at end of month)								
	0-10A	0-10B	0-10C	10-20A	10-20B	10-20C	20-30A	20-30B	20-30C	0-10A	0-10B	0-10C	10-20A	10-20B	10-20C	20-30A	20-30B	20-30C
Trichoptera																		
Beraeoptera roria																		
Helicopsyche sp.																		
Hudsonema aliena																		
Hudsonema amabilis																		
Oeconesus maori																2		
Olinga spp.			1													1	1	
Oxyethria albiceps																		
Philorheithrus agilis																	1	
Pycnocentria evecta										9							2	
Pycnocentria funerea																		
Zelandopsyche ingens																		
Edpercivalia maxima	3		1	2														
Hydrobiosella stenocerca																		
Hydrobiosis spp.			1															
Hydrobiosis parumbripennis																		
Hydrobiosis spatulata																		
Hydrochorema crassicaudatum																		
Hydrochorema tenuicaudatum																		
Plectrocnemia sp.																		
Polyplectropus sp.			1		2													
Psilochorema spp.			1	1	1		1											
Plecoptera																		
Austroperla cyrene																		
Cristaperla fimbria																		
Spaniocerca zelandica	9	2	4	3					2									
Stenoperla prasina				1														
Zelandobius spp.			2															
Zelandobius pilosus																		
Ephemeroptera																		
Austroclima jollyae																		
Coloburiscus humeralis																		
Deleatidium spp.	1						1			2								
Nesameletus sp.																		
Diptera																		
Austrosimulium sp.																		
Ceratopogonidae																		
Chironomidae	40	149	182	52	42	33	65	10	169	1	1		7	2	2	1		
Eriopterini sp. 1																		
Eriopterini sp. 2																		
Hexatomini										1								
Muscidae	3	3							1					1				
Nothodixa sp.		10		1	1			1	2									
Paradixa sp.				1		1												
Oligochaeta	1					1			1	7	3	1	2	3	7	2	2	8
Coleoptera																		
Elmidae							1											
Hydraenidae	1		1	1	1													
Hydrophilidae																		
Scirtidae																		
Mollusca																		
Potamopyrgus antipodarum			4							2	4		7		8	1		
Crustacea																		
Ostracoda											4		2			1		
Acarina					1													
Nematomorpha																		
Gordiidae										1								
Platyhelminthes									1									
Mecoptera																		
Nannochorista philpotti																		
TOTAL INVERTEBRATES	58	164	198	62	48	35	68	11	176	23	12	1	18	6	17	8	6	8

February

	SITE 3 (wet)									SITE 5 (dry)								
	0-10A	0-10B	0-10C	10-20A	10-20B	10-20C	20-30A	20-30B	20-30C	0-10A	0-10B	0-10C	10-20A	10-20B	10-20C	20-30A	20-30B	20-30C
Trichoptera																		
Beraeoptera roria																		
Helicopsyche sp.																		
Hudsonema aliena																		
Hudsonema amabilis																		
Oeconesus maori																		
Olinga feredayi		1																
Oxyethria albiceps																		
Philorheithrus agilis		2	1											1				
Pycnocentria evecta																		
Pycnocentria funerea																		
Zelandopsyche ingens																		
Edpercivalia maxima		1	1	1														
Hydrobiosella stenocerca		3																
Hydrobiosis spp.	1	1											1					
Hydrobiosis parumbripennis																		
Hydrobiosis spatulata																		
Hydrochorema crassicaudatum																		
Hydrochorema tenuicaudatum																		
Plectrocnemia sp.												4						
Polyplectropus sp.					3													
Psilochorema spp.								1										
Plecoptera																		
Austroperla cyrene																	1	
Cristaperla fimbria																		
Spaniocerca zelandica	3	2	9		4			2	1									
Stenoperla prasina				1			1											
Zelandobius spp.																		
Zelandobius pilosus																		
Ephemeroptera																		
Austroclima jollyae																		
Coloburiscus humeralis																		
Deleatidium spp.		1			2												1	
Nesameletus sp.																		
Diptera																		
Austrosimuliium sp.	1				1	1			1									
Ceratopogonidae																		
Chironomidae	134	93	171	43	31	5	5	56	53	2	2	2	1		1	1	4	
Eriopterini sp. 1																		
Eriopterini sp. 2																		
Hexatomini																		
Muscidae	1		6															
Nothodixa sp.						1												
Paradixa sp.																		
Oligochaeta		2	3	2	2			1		10	8	8	14	8	22	11	5	5
Coleoptera																		
Elmidae																		
Hydraenidae		1	3	1			1									1		
Hydrophilidae																		
Scirtidae																		
Mollusca																		
Potamopyrgus antipodarum		1								4	4	1	1	3	8	4	4	4
Crustacea																		
Ostracoda																	3	2
Acarina																		
Nematomorpha																		
Gordiidae																		
Platyhelminthes																		
Mecoptera																		
Nannochorista philpotti			1		1			1										
TOTAL INVERTEBRATES	140	105	194	48	44	7	7	61	55	16	14	15	17	11	31	17	18	11

March

	SITE 3									SITE 5								
	0-10A	0-10B	0-10C	10-20A	10-20B	10-20C	20-30A	20-30B	20-30C	0-10A	0-10B	0-10C	10-20A	10-20B	10-20C	20-30A	20-30B	20-30C
Trichoptera																		
Beraeoptera roria																		
Helicopsyche sp.																		
Hudsonema aliena			15			1	3							1		2		
Hudsonema amabilis																		
Oeconesus maori												ec			ec			
Olinga spp.														1				
Oxyethria albiceps	1																	
Philorheithrus agilis		3							1									
Pycnocentria evecta		1					1					2ec						
Pycnocentria funerea																		
Zelandopsyche ingens																		
Edpercivalia maxima	1	2	1															
Hydrobiosella stenocerca																		
Hydrobiosis spp.																		
Hydrobiosis parumbripennis																		
Hydrobiosis spatulata																		
Hydrochorema crassicaudatum																		
Hydrochorema tenuicaudatum																		
Plectrocnemia sp.																		
Polyplectropus sp.		13			6				3									
Psilochorema spp.	3		1				1											
Plecoptera																		
Austroperla cyrene																		
Cristaperla fimbria																		
Spaniocerca zelandica	6	4	14	1	2	2	3		2									
Stenoperla prasina																		
Zelandobius sp.		1			1	1												1
Zelandobius pilosus																		
Ephemeroptera																		
Austroclima jollyae																		
Coloburiscus humeralis																		
Deleatidium spp.	5	14	8	1	4													1
Nesameletus sp.		1																
Diptera																		
Austrosimulium sp.							1											
Ceratopogonidae																		
Chironomidae	48	37	56	16	29	9	166	8	10	1	3		1	4		7		
Eriopterini sp. 1																		
Eriopterini sp. 2																		
Hexatomini							1									1		
Muscidae	4		2				4				1							
Nothodixa sp.			1	1			1											
Paradixa sp.																		
Oligochaeta	1	1	10	2			15	1	2	53	10	6	12	57	6	19	11	3
Coleoptera																		
Elmidae																		
Hydraenidae	2	1		1	2		1	1										
Hydrophilidae																		
Scirtidae																		
Mollusca																		
Potamopyrgus antipodarum		1								5		2	3	7		2	7	2
Crustacea																		
Ostracoda							28	1		1		1	2	1		12	4	
Acarina																		
Nematomorpha																		
Gordiidae							1			2								
Platyhelminthes		1																
Mecoptera																		
Nannochorista philpotti	1				1		1		1									
TOTAL INVERTEBRATES	72	80	108	22	45	13	227	11	19	62	14	9	18	71	6	43	22	7

April

	SITE 3 (wet)									SITE 5 (rewetting occurred ~April 20)								
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Trichoptera																		
Beraeoptera roria																		
Helicopsyche sp.																		
Hudsonema aliena	4	2	11	3	1	2		4	21	2	4	4		14	1	2	17	
Hudsonema amabilis																		
Oeconesus maori																		
Olinga spp.	1																	
Oxyethria albiceps			1						2									
Philorheithrus agilis							2											
Pycnocentria evecta															1		3	
Pycnocentria funerea																		
Zelandopsyche ingens						1												
Edpercivalia maxima	1								1									
Hydrobiosella stenocerca																		
Hydrobiosis spp.	4	1	1											1				
Hydrobiosis parumbripennis																		
Hydrobiosis spatulata																		
Hydrochorema crassicaudatum																		
Hydrochorema tenuicaudatum																		
Plectrocnemia sp.																		
Polyplectropus sp.	6	1				5	5							1		1		
Psilochorema spp.	3	1	1			1				1			1	1			1	1
Plecoptera																		
Austroperla cyrene																		
Cristaperla fimbria	2					1	6											
Spaniocerca zelandica	13	2	10	1	1							1						
Stenoperla prasina																		
Zelandobius spp.				1														
Zelandobius pilosus		2							1									
Ephemeroptera																		
Austroclima jollyae																		
Coloburiscus humeralis																		
Deleatidium spp.	13	2	6	3		2			1	1								
Nesameletus sp.																		
Diptera																		
Austrosimulium sp.																		
Ceratopogonidae																		
Chironomidae	100	81	126	19	9	44	21	18	39	4	23	11		7	7	10	2	1
Eriopterini sp. 1																		
Eriopterini sp. 2																		
Hexatomini					1	1												
Muscidae	1	2	4									1						
Nothodixa sp.	7																	
Paradixa sp.																		
Oligochaeta	16	9	3	3	2	6	1	5	1	8	5	4	6	4	4	10	5	
Coleoptera																		
Elmidae																		
Hydraenidae				3														
Hydrophilidae																		
Scirtidae																		
Mollusca																		
Potamopyrgus antipodarum	1									6	2	2		6	1	7	2	
Crustacea																		
Ostracoda	1		1			3						1				3		
Acarina								1					1					
Nematomorpha																		
Gordiidae																	1	
Platyhelminthes																		
Mecoptera																		
Nannochorista philpotti		1					2		1									
TOTAL INVERTEBRATES	173	104	164	33	14	66	37	28	67	22	34	24	8	34	14	33	31	2

May

	SITE 3 (wet)									SITE 5 (wet)								
	0-10A	0-10B	0-10C	10-20A	10-20B	10-20C	20-30A	20-30B	20-30C	0-10A	0-10B	0-10C	10-20A	10-20B	10-20C	20-30A	20-30B	20-30C
Trichoptera																		
Beraeoptera roria																		
Helicopsyche sp.																		
Hudsonema aliena			1	2		2			3					1	3	4		
Hudsonema amabilis			1			1												
Oeconesus maori				1													2	
Olinga spp.		1										1						
Oxyethira albiceps									1									
Philorheithrus agilis																		
Pycnocentria evecta																		
Pycnocentria funerea																		
Zelandopsyche ingens																		
Edpercivalia maxima	2	1	1				2										1	
Hydrobiosella stenocerca																		
Hydrobiosis spp.									1								1	
Hydrobiosis parumbripennis																		
Hydrobiosis spatulata																		
Hydrochorema crassicaudatum																		
Hydrochorema tenuicaudatum																		
Plectrocnemia sp.																		
Polyplectropus sp.		5		3				6			1						1	
Psilochorema spp.											3			1		2		
Plecoptera																		
Austroperla cyrene																		
Cristaperla fimbria																		
Spaniocerca zelandica	7	7	7	1					1	2			1					
Stenoperla prasina																		
Zelandobius spp.										1								
Zelandobius pilosus	2	2	1															
Ephemeroptera																		
Austroclima jollyae																		
Coloburiscus humeralis																		
Deleatidium spp.	6	9	10	5	1				1		2							
Nesameletus sp.																		
Diptera																		
Austrosimuliium sp.																		
Ceratopogonidae				2														
Chironomidae	50	73	68	46	28	18	45	38	62	9	14	20	11	11	19	13	13	2
Eriopterini sp. 1																		
Eriopterini sp. 2																		
Hexatomini																		
Muscidae												1		1				
Nothodixa sp.														1				
Paradixa sp.																		
Oligochaeta	2	2	3	20		1	2	3		1	7			2	3	2	3	3
Coleoptera																		
Elmidae																		
Hydraenidae				1				1	1								1	
Hydrophilidae																		
Scirtidae		1																
Mollusca																		
Potamopyrgus antipodarum		3								1	9	1	5	2	2	2	9	1
Crustacea																		
Ostracoda				3				3	4								6	1
Acarina																		
Nematomorpha																		
Gordiidae																2		
Platyhelminthes																		
Mecoptera																		
Nannochorista philpotti				1				2	1									
TOTAL INVERTEBRATES	69	104	92	85	29	24	49	53	75	14	36	23	17	19	27	25	37	7

June

	SITE 3 (wet)									SITE 5 (wet)								
	0-10A	0-10B	0-10C	10-20A	10-20B	10-20C	20-30A	20-30B	20-30C	0-10A	0-10B	0-10C	10-20A	10-20B	10-20C	20-30A	20-30B	20-30C
Trichoptera																		
Beraeoptera roria																		
Helicopsyche sp.																		
Hudsonema aliena		1	2		3		1			5	1	1			1	1		3
Hudsonema amabilis																		
Oeconesus maori																		
Olinga spp.																		
Oxyethira albiceps																1		
Philorheithrus agilis			1															
Pycnocentria evecta				1				1										
Pycnocentria funerea																		
Zelandopsyche ingens																		
Edpercivalia maxima		1						1										
Hydrobiosella stenocerca																		
Hydrobiosis spp.		3			1					1								
Hydrobiosis parumbripennis																		
Hydrobiosis spatulata																		
Hydrochorema crassicaudatum																		
Hydrochorema tenuicaudatum							1											
Plectrocnemia sp.																		
Polyplectropus sp.			2				2		3	1		1						
Psilochorema spp.			2								1	1						
Plecoptera																		
Austroperla cyrene																		
Cristaperla fimbria																		
Spaniocerca zelandica	4	4	9				10		4	4	3			1				
Stenoperla prasina																	1	
Zelandobius spp.			1							1								
Zelandobius pilosus			1							2								
Ephemeroptera																		
Austroclima jollyae																		
Coloburiscus humeralis																		
Deleatidium spp.	4	1	9	6		1	1				2	1						
Nesameletus sp.																		
Diptera																		
Austrosimulium sp.															1			1
Ceratopogonidae																		
Chironomidae	110	72	91	32	99	30	46	69	44	17	22	15	14	13	7	10	11	17
Eriopterini sp. 1																		
Eriopterini sp. 2																		
Hexatomini																		
Muscidae		1									1					1		
Nothodixa sp.		1	1															
Paradixa sp.																		
Oligochaeta		2	2	1					1	4	4	3	4	3	1		5	2
Coleoptera																		
Elmidae																		
Hydraenidae			1															
Hydrophilidae		1																
Scirtidae			1															
Mollusca																		
Potamopyrgus antipodarum			1												2		3	2
Crustacea																		
Ostracoda					1	2	1											
Acarina																		
Nematomorpha																		
Gordiidae																		
Platyhelminthes			1															
Mecoptera																		
Nannochorista philpotti	1								6				1					
TOTAL INVERTEBRATES	119	87	126	40	104	33	62	71	58	35	34	22	19	17	12	13	20	25

July

	SITE 3 (wet)									SITE 5 (wet)								
	0-10A	0-10B	0-10C	10-20A	10-20B	10-20C	20-30A	20-30B	20-30C	0-10A	0-10B	0-10C	10-20A	10-20B	10-20C	20-30A	20-30B	20-30C
Trichoptera																		
Beraeoptera roria																		
Helicopsyche sp.																		
Hudsonema aliena			1							1	3	1					1	
Hudsonema amabilis																		
Oeconesus maori			2			1						1		2				
Olinga spp.							1											
Oxyethria albiceps																		
Philorheithrus agilis																		
Pycnocentria evecta					1	1				2	1						2	
Pycnocentria funerea																		
Zelandopsyche ingens																		
Edpercivalia maxima		1	1															
Hydrobiosella stenocerca	1																	
Hydrobiosis spp.	2														1			
Hydrobiosis parumbripennis																		
Hydrobiosis spatulata	1																	
Hydrochorema crassicaudatum																		
Hydrochorema tenuicaudatum			1															
Plectrocnemia sp.																		
Polyplectropus sp.		1				6	3						1	1				
Psilochorema spp.	1							1			2			1				1
Plecoptera																		
Austroperla cyrene																		
Cristaperla fimbria		2	2			1						2						
Spaniocerca zelandica	5	9	3		1	2	1			2	12	6		3			1	
Stenoperla prasina																		
Zelandobius spp.																		
Zelandobius pilosus	2										1	3						
Ephemeroptera																		
Austroclima jollyae																		
Coloburiscus humeralis																		
Deleatidium spp.	17	5	1			3											1	
Nesameletus sp.			1															
Diptera																		
Austrosimulium sp.																		
Ceratopogonidae																		
Chironomidae	123	101	228	10	55	83	35	65	37	39	62	62	27	54	19	9	21	22
Eriopterini sp. 1																		
Eriopterini sp. 2																		
Hexatomini											1		1					
Muscidae			1															
Nothodixa sp.		1							1									
Paradixa sp.						1												
Oligochaeta	13	18	8	1	2	3		3	1	1	17	7	5	12	8	2	7	1
Coleoptera																		
Elmidae																		
Hydraenidae	1	1											1					
Hydrophilidae																		
Scirtidae	1		1															
Mollusca																		
Potamopyrgus antipodarum		5									1	7	1	2	1	4		7
Crustacea																		
Ostracoda	7	3	9			9				1	10	2		1	1			
Acarina																		
Nematomorpha																		
Gordiidae																		
Platyhelminthes																		
Mecoptera																		
Nannochorista philpotti	1	1																
TOTAL INVERTEBRATES	175	148	259	11	59	110	40	69	39	47	110	93	36	76	30	15	34	31

August

	SITE 3 (wet)									SITE 5 (wet)								
	0-10A	0-10B	0-10C	10-20A	10-20B	10-20C	20-30A	20-30B	20-30C	0-10A	0-10B	0-10C	10-20A	10-20B	10-20C	20-30A	20-30B	20-30C
Trichoptera																		
Beraeoptera roria																		
Helicopsyche sp.																		
Hudsonema aliena	1							1				1		1	1			
Hudsonema amabilis										1								
Oeconesus maori	1				1				1	1		1	1	1	3			
Olinga spp.	1						3				1	1						1
Oxyethria albiceps																		
Philorheithrus agilis																		
Pycnocentria evecta										2							1	
Pycnocentria funerea																		
Zelandopsyche ingens																		
Edpercivalia maxima	1		1															
Hydrobiosella stenocerca																		
Hydrobiosis spp.																		
Hydrobiosis parumbripennis																		
Hydrobiosis spatulata																		
Hydrochorema crassicaudatum										1								
Hydrochorema tenuicaudatum										1								
Plectrocnemia sp.																		
Polyplectropus sp.		2			1	1	2									1		
Psilochorema sp.											1							
Plecoptera																		
Austroperla cyrene																		
Cristaperla fimbria			1			2	1		1			1		2	1			1
Spaniocerca zelandica	6		10			1	2			21	5	38	1	1	2	2	1	
Stenoperla prasina																		
Zelandobius spp.																		
Zelandobius pilosus										1		2						
Ephemeroptera																		
Austroclima jollyae												1						
Coloburiscus humeralis										2								
Deleatidium spp.		2	1						1		1	4				1		
Nesameletus sp.																		
Diptera																		
Austrosimuliium sp.														1		1		
Ceratopogonidae																		
Chironomidae	66	34	76	34	21	11	20	16	69	49	27	52	29	29	31	9	14	37
Eriopterini sp. 1																		
Eriopterini sp. 2		1																
Hexatomini																		
Muscidae																		
Nothodixa sp.										1								
Paradixa sp.																		
Oligochaeta	5		1	1	2					5	1		5	1	4	3	5	11
Coleoptera																		
Elmidae																		
Hydraenidae												1						
Hydrophilidae																		
Scirtidae																		
Mollusca																		
Potamopyrgus antipodarum										1				4	2		2	4
Crustacea																		
Ostracoda		1		2		1	2			9	2			2				
Acarina																		
Nematomorpha																		
Gordiidae																		
Platyhelminthes																		
Mecoptera																		
Nannochorista philpotti		1				2												
TOTAL INVERTEBRATES	81	41	90	37	25	18	30	17	72	95	38	102	36	42	44	17	23	54

September

	SITE 3									SITE 5								
	0-10A	0-10B	0-10C	10-20A	10-20B	10-20C	20-30A	20-30B	20-30C	0-10A	0-10B	0-10C	10-20A	10-20B	10-20C	20-30A	20-30B	20-30C
Trichoptera																		
Beraeoptera roria																		
Helicopsyche sp.																		
Hudsonema aliena		1							1	5		2		1				
Hudsonema amabilis																		
Oeconesus maori	1														2	2		
Olinga spp.			2							1		1		2			1	1
Oxyethria albiceps																		
Philorheithrus agilis																1		
Pycnocentria evecta	1									1								
Pycnocentria funerea																		
Zelandopsyche ingens		1																
Edpercivalia maxima	3	1	1															
Hydrobiosella stenocerca																		
Hydrobiosis spp.			1					1										
Hydrobiosis parumbripennis																		
Hydrobiosis spatulata																		
Hydrochorema crassicaudatum																		
Hydrochorema tenuicaudatum																		
Plectrocnemia sp.																		
Polyplectropus sp.			4		2		3			1								1
Psilochorema spp.						1			2	2			1	2				
Plecoptera																		
Austroperla cyrene																		
Cristaperla fimbria			1		3	1	1						1		1			
Spaniocerca zelandica	5		3					1		3	8	22		2	1			
Stenoperla prasina						1												
Zelandobius spp.																		
Zelandobius pilosus										6	1	4				2		
Ephemeroptera																		
Austroclima jollyae																		
Coloburiscus humeralis												1						
Deleatidium spp.	3	3	8	1		3					2	4	1		1	1		
Nesameletus sp.																		
Diptera																		
Austrosimuliium sp.								1										
Ceratopogonidae					1	2												
Chironomidae	47	54	40	10	13	36	34	8	57	38	47	47	12	22	25	14	8	17
Eriopterini sp. 1																		
Eriopterini sp. 2																		
Hexatomini															1			
Muscidae	1																	
Nothodixa sp.	1																	
Paradixa sp.																		
Oligochaeta	1	1	1	1	1				1	1		2			3	4	3	8
Coleoptera																		
Elmidae																		
Hydraenidae			1			2					1							
Hydrophilidae																		
Scirtidae																		
Mollusca																		
Potamopyrgus antipodarum										4	1		1	1	1			
Crustacea																		
Ostracoda		1	3			1	1	2		1						1		1
Acarina	2	1																
Nematomorpha																		
Gordiidae																		
Platyhelminthes	7											1						
Mecoptera																		
Nannochorista philpotti																		
TOTAL INVERTEBRATES	72	63	65	12	20	47	39	13	61	63	60	84	16	30	35	25	12	28

October

	SITE 3 (wet)									SITE 5 (wet)								
	0-10A	0-10B	0-10C	10-20A	10-20B	10-20C	20-30A	20-30B	20-30C	0-10A	0-10B	0-10C	10-20A	10-20B	10-20C	20-30A	20-30B	20-30C
Trichoptera																		
Beraeoptera roria																	1	
Helicopsyche sp.																		
Hudsonema aliena										9	1	3				1	4	1
Hudsonema amabilis										1	2	1					1	
Oeconesus maori									1		1	2			1		3	
Olinga spp.	2							1		1		2						1
Oxyethria albiceps											1							
Philorheithrus agilis										2		3	5		1			
Pycnocentria evecta		1	1							2	9	2	1				22	
Pycnocentria funerea												1						
Zelandopsyche ingens																		
Edpercivalia maxima		1	1														1	
Hydrobiosella stenocerca																		
Hydrobiosis spp.																		
Hydrobiosis parumbripennis																		
Hydrobiosis spatulata																		
Hydrochorema crassicaudatum																		
Hydrochorema tenuicaudatum																		
Plectrocnemia sp.																		
Polyplectropus sp.	8				1			6				1					1	
Psilochorema spp.	1	2					2			3	6		5	1	1		1	
Plecoptera																		
Austroperla cyrene																		
Cristaperla fimbria										1								
Spaniocerca zelandica	2	1								8	1	3					1	
Stenoperla prasina																		
Zelandobius spp.										3		1	1		1			
Zelandobius pilosus		3								30	3	23					4	
Ephemeroptera																		
Austroclima jollyae																		
Coloburiscus humeralis																	2	
Deleatidium spp.	6	7	15	1	2		1	1		5	2	20	2				5	1
Nesameletus sp.																		
Diptera																		
Austrosimuliium sp.																		
Ceratopogonidae											1							
Chironomidae	38	33	82	29	11	14	39	8	24	96	54	48	49	50	15	15	83	8
Eriopterini sp. 1																		
Eriopterini sp. 2																		
Hexatomini																		
Muscidae																		
Nothodixa sp.										1								
Paradixa sp.																		
Oligochaeta	1	4	2					1		1	1	3	1	3		2	3	1
Coleoptera																		
Elmidae														1				
Hydraenidae	2	5	2							1	2	1	1			1		
Hydrophilidae		1	1															
Scirtidae										2	1						2	
Mollusca																		
Potamopyrgus antipodarum										4	1	5			1	3		1
Crustacea																		
Ostracoda	3						1						1	1	2	1	1	
Acarina																		1
Nematomorpha																		
Gordiidae																		
Platyhelminthes			1															
Mecoptera																		
Nannochorista philpotti																		
TOTAL INVERTEBRATES	63	58	105	30	14	14	43	17	25	170	86	119	66	56	22	23	134	14

APPENDIX IV
STICKY TRAP COLLECTIONS

Site 1

	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov
Ephemeroptera												
Deleatidium												2
Nesameletus	1											
Coloburiscus												
Plecoptera												
Austroperla												
Zelandobius confusus									1			
Zelandobius furcillatus-gp	2	4	1									1
Spaniocerca zelandica	19	6	2	1	8	9	14	1		9	8	28
Cristaperla fimbria	8	7	5	1								30
Halticoperla viridans												
Trichoptera												
Hydrobiosis parumbripennis	10	2	2		2	3	2			5	2	5
H. charadraea												
H. silvicola												
H. clavigera												
H. harpidiosa												
H. soror												
H. spatulata	1			1	1							
Costachorema psaroptera												
C. xanthoptera												1
Costachorema sp. indet.												
Psilochorema bidens												
P. tautoru			2									
P.leptoharpax												
Synchorema tillyardi			1									
Neurochorema confusum												
Hydrochorema crassicaudatum		1			2							
H. tenuicaudatum	5	60	5	7	1					54	177	100
Edpercivalia maxima	63	29	20	5	17	36	70			67	72	81
E. fusca	1											
Aoteapsyche colonica												
A. tipua		4	5									1
Oxyethira albiceps			1									
Hudsonema aliena		1										
H. amabilis		1	1									
Pycnocentrodes aureola												
Pycnocentria evecta												
Beraeoptera roria												
Olinga feredayi												
O. jeanae			8									
Zelandopsyche ingens				35	138							
Oeconesus maori				1	1							
Philorheithrus agilis			55	1						1		
Hydrobiosella stenocerca	10	4	3	23	22	76	17	1	2	2	3	39
H. mixta		2		1								3
Polyplectropus altera												
TOTAL INVERTEBRATES	121	121	111	76	192	124	103	2	3	138	262	291

Site 2

	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov
Ephemeroptera												
Deleatidium	2	25	5	1							1	1
Nesameletus	2	5	3	1		1						1
Coloburiscus												
Plecoptera												
Austroperla												
Zelandobius confusus												2
Zelandobius furcillatus-gp	2											2
Spaniocerca zelandica	2	4	1					2		8	4	5
Cristaperla fimbria												1
Halticoperla viridans												
Trichoptera												
Hydrobiosis parumbripennis	7	6	1	2		6				5	9	7
H. charadraea												
H. silvicola												
H. clavigera												
H. harpidiosa												
H. soror												
H. spatulata		16	3	1	1							4
Costachorema psaroptera	2	1	2	1	1					3	1	1
C. xanthoptera												
Costachorema sp. indet.												
Psilochorema bidens												
P. tautoru	1		1			1	1			2		
P. leptoharpax												2
Synchorema tillyardi												
Neurochorema confusum												
Hydrochorema crassicaudatum												8
H. tenuicaudatum											10	2
Edpercivalia maxima	44	32	3	44	58	68	76			53	46	50
E. fusca										2		1
Aoteapsyche colonica												
A. tipua												
Oxyethira albiceps	1		3				22			6		
Hudsonema aliena		1			1							
H. amabilis			2									
Pycnocentrodes aureola												
Pycnocentria evecta												
Beraeoptera roria												
Olinga feredayi		1										
O. jeanae		2	1									
Zelandopsyche ingens		1	4	35	13							
Oeconesus maori	1			1								
Philorheithrus agilis			1									
Hydrobiosella stenocerca	3	3	1		1		1			2		1
H. mixta												
Polyplectropus altera												
TOTAL INVERTEBRATES	68	97	33	87	75	76	100	2		81	71	88

Site 3

	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Ephemeroptera												
Deleatidium	4	55	35	7	1	5	7	1		6	5	24
Nesameletus	1	16	1		1							6
Coloburiscus	2		2								1	
Plecoptera												
Austroperla												
Zelandobius confusus												2
Zelandobius furcillatus-gp	5	20	17	8	1	3					6	5
Spaniocerca zelandica			1			1	1	1		5	5	9
Cristaperla fimbria										1		
Halticoperla viridans												
Trichoptera												
Hydrobiosis parumbripennis	60	36	41	38	9	7	2			19	18	37
H. charadraea												
H. silvicola												
H. clavigera												1
H. harpidiosa							1					2
H. soror												
H. spatulata												
Costachorema psaroptera	10	4	5	3	4	2	5	2			10	3
C. xanthoptera												
Costachorema sp. indet.												
Psilochorema bidens	20	14	2	6		2	6					9
P. tautoru	2	21	5	3	10	9	3			32	20	7
P.leptoharpax	4	3	1	1								1
Synchorema tillyardi												
Neurochorema confusum	6	28	10	6								
Hydrochorema crassicaudatum											2	3
H. tenuicaudatum												
Edpercivalia maxima	43	14	5	29	23	9	4			22	19	35
E. fusca	5											1
Aoteapsyche colonica		3	10									
A. tipua												
Oxyethira albiceps		11	10	2	4	41	85	9		9	11	147
Hudsonema aliena		4	5	2								
H. amabilis		3	1									
Pycnocentrodes aureola												1
Pycnocentria evecta		2	8									
Beraeoptera roria		1	1									
Olinga feredayi		7	8	7								
O. jeanae	1											
Zelandopsyche ingens												
Oeconesus maori	3	13	4	2								
Philorheithrus agilis		1	2	1								
Hydrobiosella stenocerca	2	7	2	5	2	2	3	3				3
H. mixta												
Polyplectropus altera												
TOTAL INVERTEBRATES	168	263	176	120	55	81	117	16		94	97	296

Site 4

	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Ephemeroptera												
Deleatidium	7	41	2	6		3	2				2	21
Nesameletus	5	25		2		1						13
Coloburiscus			2	3								1
Plecoptera												
Austroperla												
Zelandobius confusus												
Zelandobius furcillatus-gp	10	19	4	4							2	10
Spaniocerca zelandica	2						1		1	3	16	18
Cristaperla fimbria												1
Halticoperla viridans												
Trichoptera												
Hydrobiosis parumbripennis	80	32	22	64	9	102	6		1	41	58	104
H. charadraea												
H. silvicola											1	1
H. clavigera												
H. harpidiosa												
H. soror				1								
H. spatulata	14		1									
Costachorema psaroptera												
C. xanthoptera		8		26						3	5	1
Costachorema sp. indet.												
Psilochorema bidens											2	3
P. tautoru	22	19	3	40	13	31	6	4		12	14	7
P.leptoharpax												
Synchorema tillyardi												
Neurochorema confusum	1	24	17	23	8	1						1
Hydrochorema crassicaudatum												
H. tenuicaudatum		1										
Edpercivalia maxima	1					2	1					
E. fusca												
Aoteapsyche colonica		28	7	9								
A. tipua												
Oxyethira albiceps	953	3069	859	672	82	604	62	553		31	3	330
Hudsonema aliena			1	8								
H. amabilis												
Pycnocentrodes aureola												1
Pycnocentria evecta		188	200	1303	41	3						
Beraeoptera roria		4										
Olinga feredayi		9	1	4								
O. jeanae												
Zelandopsyche ingens												
Oeconesus maori	17	20	15	21								1
Philorheithrus agilis												
Hydrobiosella stenocerca	5	4	2				1	1				1
H. mixta												
Polyplectropus altera		2	2									
TOTAL INVERTEBRATES	1117	3493	1138	2186	153	747	79	558	2	90	103	514

Site 5

	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Ephemeroptera												
Deleatidium	2	15	1			4	2					2
Nesameletus	1											3
Coloburiscus		7	1	1								
Plecoptera												
Austroperla												
Zelandobius confusus												
Zelandobius furcillatus-gp	9	12	2		1						4	11
Spaniocerca zelandica										5	2	2
Cristaperla fimbria												
Halticoperla viridans												
Trichoptera												
Hydrobiosis parumbripennis	12	3	7			4		2	3	10	5	3
H. charadraea												
H. silvicola												
H. clavigera												
H. harpidiosa												
H. soror												
H. spatulata												
Costachorema psaroptera												
C. xanthoptera											5	
Costachorema sp. indet.												
Psilochorema bidens							3				1	
P. tautoru	9	6	6	3		2	2	2		12		
P.leptoharpax												
Synchorema tillyardi												
Neurochorema confusum	2	3	2			3						1
Hydrochorema crassicaudatum												1
H. tenuicaudatum												
Edpercivalia maxima												
E. fusca												
Aoteapsyche colonica	1	5	1									
A. tipua												
Oxyethira albiceps	731	2436	1095	68	48	470	211	136	1	13		46
Hudsonema aliena												
H. amabilis		1										
Pycnocentrodes aureola	1											1
Pycnocentria evecta	1	122	25	6								
Beraeoptera roria		1	1									
Olinga feredayi		4	33									
O. jeanae												
Zelandopsyche ingens												
Oeconesus maori	2	1	3									
Philorheithrus agilis												
Hydrobiosella stenocerca	2											
H. mixta												
Polyplectropus altera			1	3								
TOTAL INVERTEBRATES	773	2616	1178	81	49	483	218	140	4	40	17	70

APPENDIX V
UPSTREAM MOVEMENT SAMPLES

December (traps were in stream for 1 month)

SITE	3A	3B	3C	5A	5B	5C
Trichoptera						
Beraeoptera roria						
Hudsonema aliena						
Hudsonema amabilis						
Oeconesus maori				1		
Olinga spp.						
Oxyethira albiceps						
Philorheithrus agilis						
Pycnocentria evecta						
Aoteapsyche colonica						
Edpercivalia maxima	1		1			
Hydrobiosis spp.						1
Hydrobiosis spatulata						
Psilochorema spp.				1	1	
Plecoptera						
Spaniocerca zelandica		5	2	1	8	2
Stenoperla prasina						
Zelandobius spp.						
Zelandobius pilosus						
Ephemeroptera						
Austroclima jollyae						
Deleatidium spp.		5			1	3
Nesameletus sp.				1		
Diptera						
Austrosimuliium sp.						6
Chironomidae	181	175	83	100	91	105
Muscidae				1	1	1
Nothodixa sp.				1		
Oligochaeta	1		1	3	10	7
Coleoptera						
Hydraenidae						
Scirtidae						
Mollusca						
Potamopyrgus antipodarum						
Acarina						
Platyhelminthes						

January (traps were in stream for 24 hours)

SITE	3A	3B	3C	5A	5B	5C
Trichoptera						no data
Beraeoptera roria						
Hudsonema aliena				1		
Hudsonema amabilis						
Oeconesus maori						
Olinga spp.						
Oxyethira albiceps		1		1		
Philorheithrus agilis						
Pycnocentria evecta				3	1	
Aoteapsyche colonica					1	
Edpercivalia maxima						
Hydrobiosis spp.				1		
Hydrobiosis spatulata						
Psilochorema spp.				2		
Plecoptera						
Spaniocerca zelandica		2		2	2	
Stenoperla prasina					1	
Zelandobius spp.				1		
Zelandobius pilosus						
Ephemeroptera						
Austroclima jollyae						
Deleatidium spp.	1	1	1	24	17	
Nesameletus sp.				1		
Diptera						
Austrosimuliium sp.		4	3	1		
Chironomidae	5	6	7	6	4	
Muscidae						
Nothodixa sp.		1	1			
Oligochaeta		1		1		
Coleoptera						
Hydraenidae						
Scirtidae				3		
Mollusca						
Potamopyrgus antipodarum						
Acarina						
Platyhelminthes						

February (traps were in stream for 24 hours)

Site 5 dry

SITE	3A	3B	3C	4A	4B	4C
Trichoptera						
Beraeoptera roria						
Hudsonema aliena						
Hudsonema amabilis						
Oeconesus maori						
Olinga spp.						
Oxyethria albiceps	1		1			
Philorheithrus agilis						
Pycnocentria evecta			1	1	3	
Aoteapsyche colonica						
Edpercivalia maxima	1					
Hydrobiosis spp.						
Hydrobiosis spatulata	1					
Psilochorema spp.						
Plecoptera						
Spaniocerca zelandica	1	2			1	
Stenoperla prasina						
Zelandobius spp.			1			1
Zelandobius pilosus						
Ephemeroptera						
Austroclima jollyae						
Deleatidium spp.	2		2			
Nesameletus sp.						
Diptera						
Austrosimuliium sp.		2				
Chironomidae	56	43	42	20	15	19
Muscidae					1	
Nothodixa sp.	3	14	6	2	5	4
Oligochaeta	4	2				1
Coleoptera						
Hydraenidae					1	
Scirtidae						
Mollusca						
Potamopyrgus antipodarum						
Acarina						
Platyhelminthes			3			

March (traps were in stream for 24 hours)

Site 5 dry

SITE	3A	3B	3C	4A	4B	4C
Trichoptera						
Beraeoptera roria						
Hudsonema aliena						
Hudsonema amabilis						1
Oeconesus maori						
Olinga spp.						
Oxyethria albiceps	1	1				
Philorheithrus agilis						
Pycnocentria evecta						
Aoteapsyche colonica						
Edpercivalia maxima						
Hydrobiosis spp.						1
Hydrobiosis spatulata						
Psilochorema spp.						
Plecoptera						
Spaniocerca zelandica	1			1		
Stenoperla prasina						
Zelandobius spp.						1
Zelandobius pilosus						
Ephemeroptera						
Austroclima jollyae	1					
Deleatidium spp.	1	7	1			
Nesameletus sp.		2				
Diptera						
Austrosimuliium sp.			8			
Chironomidae	2	20	5	2		2
Muscidae						
Nothodixa sp.	1	8	10	3		
Oligochaeta		1		1		
Coleoptera						
Hydraenidae				1		
Scirtidae						
Mollusca						
Potamopyrgus antipodarum						
Acarina						
Platyhelminthes		1				

April (traps were in stream for 24 hours)

				Site 5 dry		
SITE	3A	3B	3C	4A	4B	4C
Trichoptera						
Beraeoptera roria				1	1	1
Hudsonema aliena		5	2	1	10	3
Hudsonema amabilis					1	
Oeconesus maori						
Olinga spp.					1	
Oxyethria albiceps	1	2	7		1	
Philorheithrus agilis						
Pycnocentria evecta				2	1	3
Aoteapsyche colonica						
Edpercivalia maxima						
Hydrobiosis spp.						
Hydrobiosis spatulata			1			
Psilochorema spp.		1			1	
Plecoptera						
Spaniocerca zelandica		3	1			1
Stenoperla prasina						
Zelandobius spp.	1				3	1
Zelandobius pilosus		9			2	
Ephemeroptera						
Austroclima jollyae						
Deleatidium spp.	2	2	2	5	6	1
Nesameletus sp.		3			2	2
Diptera						
Austrosimuliium sp.						
Chironomidae	1	52	9	7	5	10
Muscidae						
Nothodixa sp.		2	3		2	
Oligochaeta	2	16		1	4	12
Coleoptera						
Hydraenidae						
Scirtidae						
Mollusca						
Potamopyrgus antipodarum					2	
Acarina						
Platyhelminthes						

May (traps were in stream for 24 hours)

SITE	3A	3B	3C	5A	5B	5C
Trichoptera						
Beraeoptera roria						
Hudsonema aliena					1	1
Hudsonema amabilis						
Oeconesus maori						
Olinga spp.						
Oxyethria albiceps						
Philorheithrus agilis						
Pycnocentria evecta						
Aoteapsyche colonica						
Edpercivalia maxima					1	
Hydrobiosis spp.	1		2		1	
Hydrobiosis spatulata						
Psilochorema spp.						
Plecoptera						
Spaniocerca zelandica	1	1				
Stenoperla prasina						
Zelandobius spp.						
Zelandobius pilosus	3		1			
Ephemeroptera						
Austroclima jollyae						
Deleatidium spp.	2	3	1			
Nesameletus sp.						1
Diptera						
Austrosimuliium sp.	6	6	9			
Chironomidae	5	16	6	1	1	
Muscidae						
Nothodixa sp.	2					
Oligochaeta	3	2		2	4	4
Coleoptera						
Hydraenidae			1			
Scirtidae						
Mollusca						
Potamopyrgus antipodarum						
Acarina						
Platyhelminthes						